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Vol. XXVII SECTION-B Part V

STUDIES ON FUNAMBULUS PALMARUM LINN., THE INDIAN PALM SQUIRREL:

PART II: THE FUNCTIONAL ANATOMY OF THE HEART

By

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(Received on 4th February, 1957)

The typical mammalian heart of the squirrel lies obliquely in the pericardial cavity in the *mediastinum* near the lungs, the apex pointing obliquely to the left side. The openings of the *anterior vena cava* lie close together in the dorsal wall of the right auricle, while the single opening of the *posterior vena cava* lies medially. The much smaller left auricle receives the *pulmonary veins* by 4 apertures usually. The common *pulmonary artery* originates from the left ventricular apex and forks midway across the left auricle. The *systemic artery* originates from the right ventricle higher than the pulmonary.

The ventricles contain 2 sets of *papillary muscles*, the superior and the inferior. The *musculi pectinati*, giving attachment to chordae tendinae of the mitral valve, are spread over a large field. The conductile system is well-developed, with an S. A. node, an A. V. node and a *bundle of His*; and the contractile mechanism and control of blood-flow are explained.

INTRODUCTION

The present contribution forms the *second* part of a series of detailed studies on the functional anatomy of the Indian Palm Squirrel, which is used as a mammalian type in most of the Universities of India, Burma, Pakistan and Ceylon.

It is hoped that these studies will fill up a conspicuous gap in our knowledge of the oriental sciuridae.

Although the structure of the mammalian heart is very well known on account of detailed investigations on human (Gray 1954, Keith and Flack 1906), rat (Prakash 1954A) and other (Kant 1893) hearts, the squirrel heart presents so many peculiarities and also semblances to the human heart, that the functional anatomy of the squirrel-heart is worth-while presenting. Besides, the squirrel is used as a mammalian type in many Universities in India, Burma, Pakistan and Ceylon, and no description of its heart is available. Kent (1893) stated that the mammalian heart does not have any break in the muscular continuity between atria and ventricles. Prakash (1954A) on the other hand maintains that there is a break in muscular continuity in all mammals, the 'bundle of His' being the only connection between the atria and ventricles, and confirms the earlier view of Kistin (1949). The present investigation gives a summary account of the squirrel heart and the mechanisms concerned with initiation, control and conduction of the cardiac stimulus.

GENERAL

The heart of the squirrel (Fig. 1) is a hollow muscular organ about the size of an outsize bean, enclosed in a thin pericardial membrane consisting of an outer *parietal* and an inner *visceral layer* immediately investing the heart. The *pericardial cavity* between the two is narrow and contains a little pericardial fluid. The heart lies somewhat obliquely to the left in the thorax between the two *pleural sacs* enclosing the lung and in a freshly exposed animal the anterior third only lies to the right of the median line, the rest two-third lying on the left with the ventricular apex pointing obliquely left. The *mediastinal space* between the two pleural sacs is divisible into four parts, the anterior, the dorsal, the middle and the ventral, the middle part being the widest and lodging the heart. In the fresh condition the right auricle is about one third the size of the ventricular cone, while the left auricle is somewhat smaller. The division into right and left ventricles is indicated externally by the oblique coronary groove, while internally a muscular partition extends between the two auricles (*inter-auricular septum*) on to the apex of the ventricular cone as the *inter-ventricular septum.*

THE WALLS

The walls of the ventricles are thicker than those of the auricles and the wall of the left ventricle is thicker than that of the right ventricle (Fig. 2). This is because the left ventricle has to pump blood to all parts of the body, the right pumping only to the lungs. The heart-wall has three layers: *endocardium*, *myocardium* and *epicardium.* The *endocardium* consists of a thin layer of connective tissue and an endothelial layer continuous with that of blood vessels. The *myocardium* is a thick muscular layer consisting of fibres of *cardiac muscle* which have anastamosing connections with one another. The muscles of the myocardium are wound circularly around the heart and arranged in such a way that the fibres of the outer layers run at right angles to those of the inner layers, ensuring maximum contraction. The *epicardium* is a thin layer of connective tissue covered by the serous membrane which lines the pericardial cavity. The muscles of the auricles are mostly independent of the muscles of the ventricles and the two are separated by an *auriculo-ventricular septum* of connective tissue. But there is an *auriculo-ventricular bundle* (*bundle of His*) of specialised muscle fibres, which extends from the inter-auricular septum to the inter-ventricular septum, and serves to convery the rhythm of contraction from the auricles to the ventricles.

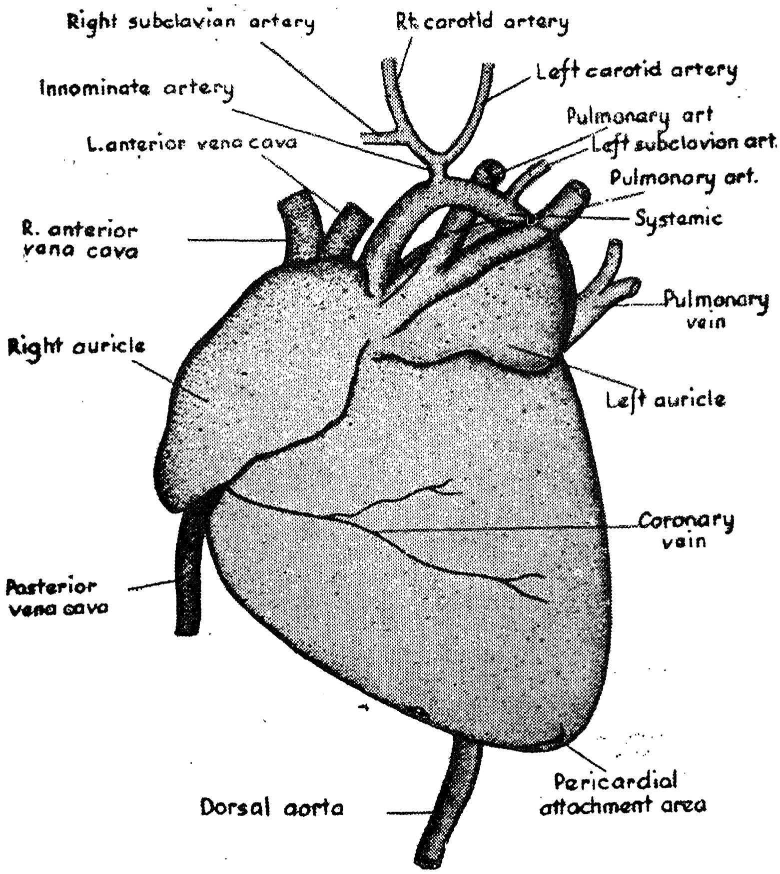

Fig. 1. The Heart of Squirrel (external), showing roots of main vessels.

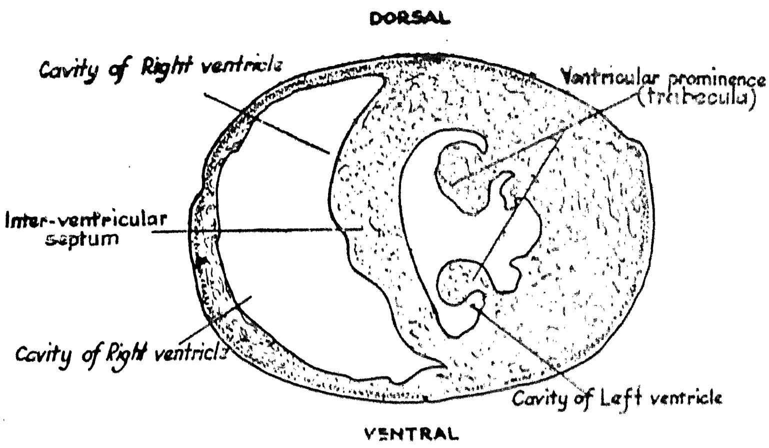

Fig. 2. T. S. Heart to show size and shape of ventricles.

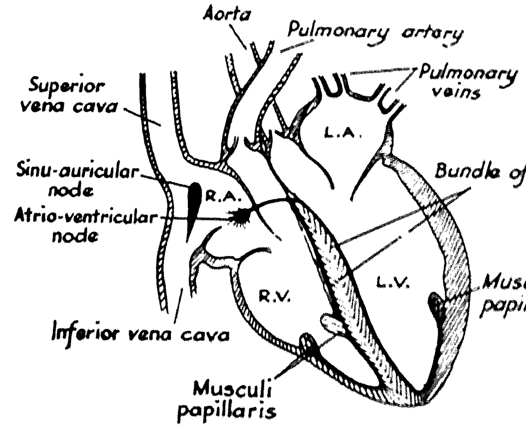

Fig. 3. The conductile mechanism of the heart

THE CONDUCTILE MECHANISM

The conductile mechanism of the squirrel heart is typical mammalian. The nerve supply is through the sympathetic thoracolumbar fibres known as the *accelerator nerve* as well as the vagus (X) nerve which carries parasympathetic fibres. Stimulation of the accelerator nerve speeds up the heart beat, while stimulation of the vagus retards it. But if both these stimulating mechanisms (the nerves) are cut, the heart continues to beat normally. This is because the heart has within itself two *neuro-muscular centres* which are partly nervous and partly muscular. The first such centre is called the *sinuauricular node* or *sinuatrial node* (S. A. node, also named the *Keith-Flack node*) which lies imbedded in the wall of the right auricle at the junction of the superior and inferior vena cavae.

The second centre, called the *atrio-ventricular node* (auriculo-ventricular node, A-V. node or the *node of Tawara*) lies in the septum between the right auricle and the right ventricle (Fig. 3). Its fibres are continued into the inter-ventricular septum up to the bases of the papillary muscles and are together known as the *bundle of His* referred to above. These two nodes together with the bundle of His cooperate to control the rhythm of the heart beat even in the absence of nervous stimulation or control.

THE AURICLES

The cavity of the right auricle is larger than that of the left auricle, and into it open three large veins, the *right precaval*, the *left precaval* and the *postcaval*. The right opens into its anterior part, the second antero-laterally near the first, while the third opens dorsally, all the openings appearing crescentric normally. The cavity of the right auricle communicates with the cavity of the right ventricle by a wide auriculo-ventricular (or atrio-ventricular) opening guarded by a *funnel-shaped tricuspid valve* composed of three membranous flaps attached to the papillary muscles of the ventricle by tendinous threads called *chordae tendinae* (Fig. 4). The right auricle receives the entire venous blood from the whole body (except the lungs) and passes it into the right ventricle, the tricuspid valve flaps meeting together and closing the atrio-ventricular opening when the ventricle contracts. The cavity of the left auricle is smaller than that of the right auricle and into its dorsal aspect open the right and left pulmonary veins. The left auriculo-ventricular opening is guarded by a *bicuspid valve* or *mitral valve* composed of two membranous flaps with chordae tendinae and papillary muscles, which prevent back flow of blood from the left ventricle into the left auricle.

THE VENTRICLES

The right ventricle has a much larger cavity than the left but the left ventricle not only has a much thicker wall than the right, but also has a pair of thick ventricular prominences jutting into its cavity as trabeculae (Fig. 5). This is so because the right ventricle receives the entire venous blood of the body through the right auricle and thus its cavity must be larger, yet since it pumps blood only to the lungs, its wall is thicker. Whereas the left ventricle pumps blood to all other parts of body and is correspondingly more muscular. Both the right and left venticles have *columnae carnae* or muscular ridges projecting into their cavities, but these are more marked in the left than in the right ventricle. A series of six transverse sections (Fig. 5) shows the disposition of the right and left ventricular cavities. It is apparent that the thin-walled right venticle has its large cavity arranged as a crescent, which may partially enclose the cavity of the left ventricle in a contracted state. Again the cavity of the right increases in extent as we proceed from the ventricular apex towards the auricles; while the cavity of the left ventricle is much reduced near the auriculo-ventricular opening.

The right ventricle gives rise to the *pulmonary artery* at its left anterior-angle, the entrance to the artery being guarded by three simple pouch-like semilunar valves to prevent the return of blood into the ventricles. The left ventricle gives rise to the *aorta or systemic arch* at its right anterior angle, the entrance to which is also guarded by three semilunar valves. The coronary artery arises from the aorta just beyond the semilunar valves, while the *coronary vein* (Fig. 1) runs parallel to the artery and returns blood to the terminal part of the left precaval.

COURSE OF CIRCULATION

The entire venous blood from the body is poured into the right auricle through the precaval and the postcaval. The beginning of the *wave of contraction* of the heart starts at the *sinu-auricular node*, the first to contract being the right auricle. This causes the entire venous blood to be pumped through the tricuspid valve into the right ventricle. Simultaneously, the blood from the lungs is poured into the left auricle through the pulmonary veins. The wave of contraction now pumps the blood from the left auricle through the bicuspid (mitral) valve into the left ventricle. The *atrio-ventricular node* now comes into play through the bundle of His, and the wave of contraction passes almost simultaneously over the two ventricles. The contraction of the right ventricle sends all the deoxygenated blood, through the pulmonary arteries, for aeration into the lungs, while the powerful contraction of the left ventricle pumps oxygenated blood through the aorta to all parts of the body.

We thus find that the same blood, from any point in the body to complete one complete cycle and reach the same point, has to pass through the heart twice : once in order to reach the lungs (through right auricle-right ventricle-pulmonary trunk), and again a second time through the heart in order to reach the same point in the body (through left aùricle-left ventricle-systemic trunk). This double passage of the same blood (through the heart) to complete one cycle of circulation may be called *double circulation.*

THE, CARDIAC CYCLE

In the lower vertebrates (e. g. frog, turtle etc.) the cardiac musculature is continuous from the venous to the arterial and of the heart; while in mammals there is discontinuity. The ordinary myocardium of the atria is distinct from that of the ventricles. This separation is due to development of the fibrous atrio-ventricular septum.

A bundle of muscle fibres that differs histologically (as already described) from ordinary cadiac muscle, effects a connection for the conduction of the cardiac impulse from the right auricle to the ventricles. It is known commonly as the "A-V Bundle" or the "Bundle of His". Each branch of the bundle of His gives off several branches which subdivide to form finally a reticulated sheet of tissue beneath the endocardium with branches which pervade the myocardium. The muscle cells composing this sheet are primitive in character and are larger than those composing the A-V node and the bundle of His. They have striated myofibrils restricted to their periphial cytoplasms and are called *fibres of Purkinje*.

Embedded in the wall of the right atrium at the junction of the superior vene cava and the right auricle appendage is another mass of nodal tissue known as the Sino-atrial or S. A. node. The cardiac impulse, which sweeps over the heart in advance of the mechanical events, originates in this node and it is thus known as the *pacemaker* of the mammalian heart. In the heart of lower vertebrates, the beat

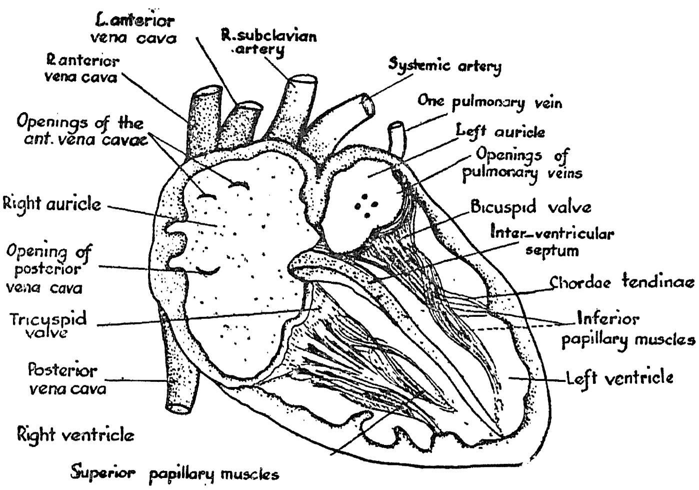

Fig. 4. The openings, chambers and valves of the heart.

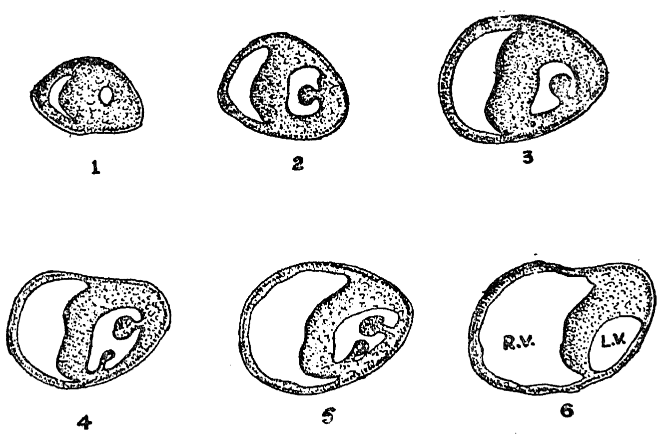

Fig. 5. Serial sections of the ventricles from posterior to anterior end.

originates in the sinus venosus. From this S. A. node, the cardiac impulse is conducted to the A-V node and across the inter-atrial septum to the left auricle through the ordinary muscular heart tissue. From the A-V node the wave spreads along the A. V. bundle, its rights and left branches, and the Purkinje fibres to the ventricular musculature. As each part of the myocardium is excited by the spreading exitation wave, it begins to contract. The special tissues of the mammalian heart are therefore the sinuatrial node, the A. V. node, the A. V. bundle of His and the Purkinje system of fibres. There are also morphological and physiological evidences that accessary pathways may exist in some mammals and man for conduction between atrial and venticular musculature. If they do exist, they are apparently of no great physiological import in the squirrel.

The *cardiac cycle* is the sequence of the atrial and ventricular events which occur during each beat of the heart. More strictly it is the succession of events which follow each discharge of the S. A. node. The duration of the cardiac cycle—*atrial systole* and *atrial diastole, ventricular systole* and *ventricular diastole,* varies inversely with the cardiac rate. Just prior to atrial systole, the atria and ventricles are lelaxed. During this period the aortic and pulmonary valves are closed and the atrio-ventricular valves open. Blood pours into the atria from the great veins and then from atria into the ventricles. Towards the end of ventricular diastole the atria contract and supercharge the ventricles. The amount of blood forced into the ventricles by systole of the atria depends on (1) the force of atrial systole, (2) the time in ventricular diastole when atrial systole occurs, and (3) the volume of blood already in the ventricles. The right atrium contracts slightly before the left since its musculature is excited earlier.

As the ventricular musculature contracts in the *contraction phase,* the intraventricular pressures rise, the A. V. valves are closed, and the ventricles are for a short time closed cavities since the pulmonary and aortic valves are still closed. During this interval of isometric contraction the pressure in the ventricles rises sharply. And when the right and left intra-ventricular pressures exceed the intro-pulmonary and intra-aortic pressures respectively, the pulmonary and aortic valves open. At first rapid ejection of blood occurs and then the systolic discharge lessens. Ventricular outflow cuntinues as long as the pressure in the ventricles is higher than that in the great arteries.

The ventricles finally enter their *relaxation phase,* the intraventricular pressures fall, and the pulmonary and aortic valves close. At this time the atria are relaxed and blood is pouring into their cavities from the great veins. The pressure in the atria, which has been rising during the greater part of the ventricular systole now exceeds that in the ventricles, and the A. V. valves open. The inflow of blood into the ventricles is at first rapid and then reduced, the period of reduced ventricular inflow being called *diastasis.* A cardiac cycle has thus been completed.

ACKNOWLEDGEMENTS

I am indebted to Sir G. R. De Beer, F. R. S. and Professor J. Z. Young, F. R. S. of London for initiating me into the mysteries of functional anatomy and the life of Mammals. To Prof. J. H. Parpart of New York I am thankful for clearing up certain problems in physiology at Woods Hole, U. S. A., during my stay there.

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STUDIES ON FUNAMBULUS PALMARUM LINN., THE INDIAN PALM SQUIRREL :

PART III. THE VENOUS SYSTEM

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The author has accounted for the veins of the head and neck, the veins of the upper extremity the thorax, the abdomen and pelvis, and the veins of the lower extremity. The main features are : (1) the right precaval receives the azygos, coronary, subclavian, and is formed by the union of dorsal (internal) and ventral (external) jugulars ; (2) there is a jugular loop (or ring) in the neck region on each side ; (3) the large hepatic portal and the smaller hepatic veins lie close together ; (4) the renals, the ilio-lumbars and the iliacs are spaced almost equally on the posterior vena cava ; and (5) unlike the arteries, the superficial femoral and the sciatic form a definite loop on the inner region of the hind limb.

INTRODUCTION

The present contribution forms the third part of a series of detailed studies on the functional anatomy of the Indian Palm Squirrel, which is used as a mammalian type in most of the Universities of India, Burma, Pakistan and Ceylon. It is hoped that these studies will fill up a conspicuous gap in our knowledge of the Oriental Scivridae. General comparisons with other Rodents will be made in a later contribution. It may be mentioned, however, that the presence of two anterior vena cavae makes the squirrel of rather ancient stock amongst mammals—along with monotremes and elephants.

THE PULMONARY VEINS

The pulmonary veins, conveying oxygenated blood from the lungs to the left atrium or auricle, arise in the capillary network of the alveoli and unite to form one vein for each lobule of the lung. These further join to form one vein for each lobe of the lung which unite in such a way that finally two veins are formed from each lung. The two veins from each lung finally open into the left auricle by two openings normally.

THE SYSTEMIC VEINS

These veins return the blood from all parts of the body to the right auricle ; i.e., the blood distributed by the systemic arteries is returned by the systemic veins which may be conveniently divided into three sets—superficial veins, deep veins and venous sinuses.

Superficial veins—are usually located just beneath the skin and can be seen without dissection merely by removal of the superficial skin. They are usually veins returning blood from skin and fascie, and may have many anastomoses with the deep veins.

Deep veins—usually run along with the arteries and may be even enclosed in the same sheath. But in certain parts of the body the deep veins do not accompany arteries, such as the veins of the skull and vertebral canal, the hepatic veins and the larger veins returning blood from the bones.

Venous sinuses—are canals found in the interior of the skull of which the lateral, the superior, the inferior and the occipital sinuses are the largest. The walls of these sinuses are devoid of muscular tissue.

According to their connections the systemic veins are divided into three groups :

(1) *The Veins of the heart* : which open into the right auricle via the coronary sinus, viz. the coronary sinus and two cardiac veins.

(2) *The Veins of the Anterior vena cava*—(Precaval) : which collect blood from the head, neck, upper extremities, thorax and the Azygos veins and pour it into the right auricle.

(3) *The Veins of the posterior vena cava*—(Postcaval) : which receive blood from the abdomen, the pelvis, and the lower extremities and pour the blood into the right auricle.

1. THE VEINS OF THE HEAD AND NECK

The entire blood from the head and neck flows on each side into two main veins-the *Dorsal (external) jugular* and the *Ventral (Internal) jugular*. The most outstanding fact about veins of the head and neck of the squirrel is the feature that the *external and internal jugulars are joined by a commissural vein so as to form a large loop or circle*, where the vein is thickened to form the *Jugular loop*. The boundaries of the external and internal jugular veins are obliterated at the anterior margin of the loop where it receives the entire blood from the jaws, the face, the nose, the eyes, the ears, and the brain. This intermingling of blood coming from the brain with that of the face before entering the main external or internal jugular vein is not recorded to my knowledge in any other mammal of India, and thus this is the first record of such a jugular loop in mammals from India. The loop may be conveniently divided into three parts and their tributaries described accordingly, viz. the *dorsal jugular*, the *ventral jugular* and the *anterior jugular*. The anterial jugular is however not homologous with the vein with a similar name in man.

A. *The Anterior Vena Cava.* The right and left Precavals (Ant. V. Cavae) are symmetrical in the squirrel except for the *azygos* and *coronary* which fall into the right precaval alone. Each precaval, after traversing the thorax and reaching the base of the neck receives two stout veins, the *subclavian* externally and the *pharyngotracheal* internally, after which it passed anteriorly as the common jugular vein. The *common jugular* is very short and receives a superficial brachial vein at the point of its bifurcation to from the external and internal jugulars.

(1) *External jugular.* The dorsal or external jugular is a stout vein forming the outer limb of the *Jugular loop*, and curves medially to join the internal jugular through the anterior jugular at the anterior end of the neck near the base of the great masseter muscle. It received blood from the superficial brachial, occipital, cervical, parietal, and scapular veins, and is formed by the junction of the anterior jugular and the cerebrofacial veins, one on each side of the head.

(i) *Superficial brachial*: collects blood from the skin and fascia of the deltoid region of the arm and falls into the external jugular at its junction with the internal.

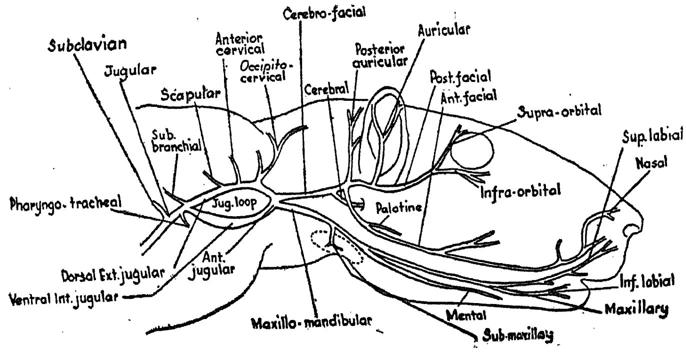

Fig. 1. The veins of the head and neck in side view.

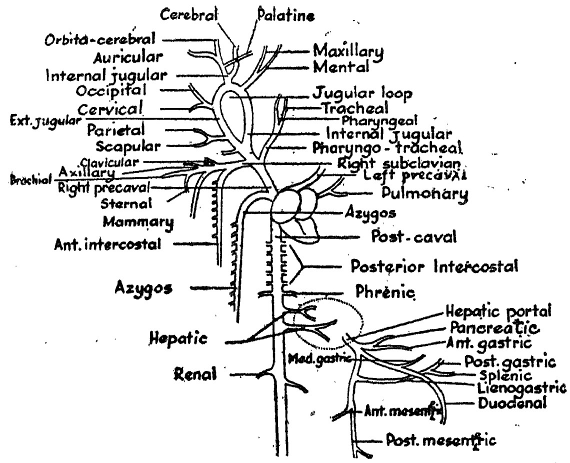

Fig. 2. The veins of the anterior half of the Squirrel (Ventral view).

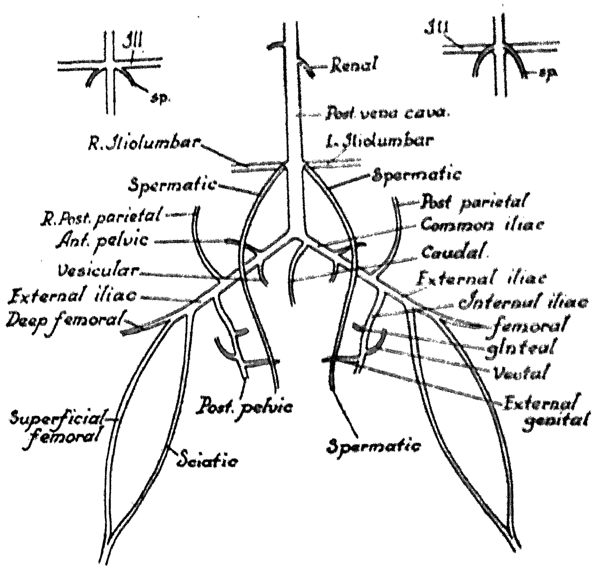

Fig. 3. The posterior veins of male squirrel.

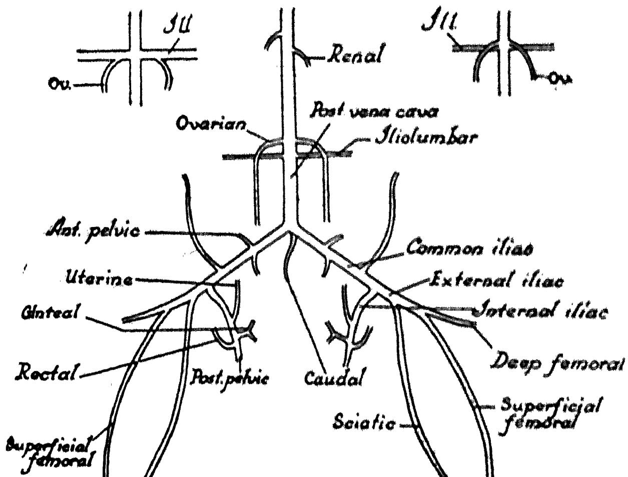

Fig. 4. The posterior veins of female squirrel.

(ii) *Scapulo-parietal*: falls into the external jugular about one third of its way up the jugular loop and is formed by the scapular vein coming from the scapular muscles and the parietal vein collecting blood from the skin of the shoulder and postero-dorsal part of neck.

(iii) *Occipito-cervical* : joins the external jugular about two thirds of its way up the neck and receives blood from a large *occipital* vein from base of skull and a cervical vein from the anterior region of the neck muscles.

(2) *Anterior jugular*. This is a semicircular commissural vein joining the external and internal jugulars at the anterior end and receives the entire blood from the face, eyes, ears, temporal region of head and the brain.

(i) *Anterior facial* : brings blood from the part of the face in front of the eyes as well as the nose through a nasal vein, and meets the palatine vein.

(ii) *Palatine vein*: from the palate and runs posteriorly to fall into a common vein, formed by the union of posterior facial and posterior auricular veins, to constitute the common facial vein.

(iii) *Posterior facial*: collects blood from the region of the face behind the eyes and also from the eye-region through the supra-orbital and infra-orbital branches.

(iv) *Auricular vein* : brings blood from external ear and falls into the posterior facial vein.

(v) *Posterior auricular*: is a large vein with many branches collecting blood from the mastoid and temporal region behind the ear.

(vi) *Cerebral* : is a large vein which emerges from the cranium, and its branches the superior and inferior cerebrals collect blood from the cerebral (cranial) sinuses. The cerebral and the common facial meet and the common cerebro-facial vein joins the anterior jugular loop.

(3) *Internal jugular or Ventral jugular*. This is continuous with the anterior jugular, the cerebral vein of which comes from the interior of the skull and emerges from the skull through the jugular foremen at the base of the skull. Thus from its functional aspect the internal jugular should be stated to begin at the junction of the cerebral with the common facial vein, i. e. before this short cerebro-facial vein falls into the anterior jugular, From the morphological angle, however, the external jugular is formed by union of the posterior facial vein with the posterior auricular vein. We have therefore the anomaly that the short stout cerebro-facial vein falling into the anterior jugular is both the external and internal jugular. It is possible that the two are actually fused into one at this point and that the new anterior jugular vein of squirrel is really the external jugular in its dorsal half and the internal jugular in its ventral half, the two joining anteriorly to receive the cerebral and the common facial veins.

(i) *Maxillary vein*: one on each side, is a stout superficial vein, running on the outer surface of the cheek from the angle of the mouth, where its branches (a) *superior labial* and (b) *inferior labial*, collect blood from the upper and lower lips respectively. On reaching the angle of the jaws the maxillary receives the submental vein.

(ii) *Submental*: brings the entire blood from the region of the chin and falls into the maxillary.

(iii) *Submaxillary* : is a small vein arising from the large submaxillary gland and falling into the common maxillo-mental vein.

2. THE VEINS OF THE THORAX

(1) *The Anterior Vena Cava.* This is formed, on each side as already indicated, by the union of the common jugular, the subclavian and the pharyngotracheal. The right precaval passes almost directly backwards across the right subclavian artery and enters the anterior part of the right auricle. The left precaval crosses the left subclavian artery as well as the arch of the aorta, reaching the right auricle form its dorsal surface.

(2) *The Subclavian.* This falls on the outer side of the precaval and is described with the veins of the upper extremity.

(3) *The Pharyngo-tracheal.* This is the smallest of the veins forming the anterior vena cava and originates by the junction of a tracheal and a pharyngeal vein collecting blood from the trachea and pharynx respectively.

(4) *The Azygos.* This is asymmetrical, being present only on the right side, and begins its course near the right renal vein. It ascends the right side of the vertebral column up to the middle thoracic region, receiving blood from the vertebral column and intercostal muscles through nine branches, and then arches over the base of the right lung to open into the posterior part of the right precaval vein.

(5) *The Pulmonary veins* have been already described.

(6) *The Thoracic Posterior Vena Cava.* The anterior portion of the precaval lies in the thorax, where, after perforating the diaphragm, it runs anteriorly along the right side of the aorta to terminate by entering the right auricle in its lower half.

(7) *The Phrenics.* These are a pair of small veins lying on the anterior (thoracic face of the diaphragm, one on each side of the vena cava, and communicating directly with the postcaval, into which they carry the blood distributed in the diaphragm through the phrenic arteries.

(8) *The Posterior Intercostals.* These are five pairs of short veins falling laterally directly into the thoracic post-cava. They collect blood from the last five intercostal muscles.

3. THE VEINS OF THE UPPER EXTREMITY

The blood from the fore-limbs is returned by a system of deep veins, the metacarpal veins, the radial and ulnar veins, which finally form the brachial that falls into the *subclavian vein* with its different branches. On its anterior face the subclavian receives the clavicular, axillary and brachial veins and on its posterior face the sternal, the pectoral and the anterior intercostal veins. The distribution of the branches of the sub-clavian vein is as follows :—

(1) *The Clavicular* : is the first vein nearest the root of the sub-clavian on its anterior face. It arises by several branches from the skin and muscles of the clavicular region and runs postero-medially to fall into the subclavian.

(2) *The Axillary* : the second vein on anterior face of subclavian is a thin vein returning blood from the skin and muscles of the axillary region. This is not comparable with the axillary of man.

Fig. 5. The veins arising from the intestinal loop (Photo).

(3) *The Brachial*: is the terminal vein of the subclavian and brings blood from the entire forelimb by its various branches: (i) the *metacarpal veins* of the metacarpus; (ii) the *radial vein* running on the inner side of the arm; (iii) the *ulnar vein* running on the outer side of the fore-arm. Both (ii) and (iii) receive blood from the hand and arm, and finally fall into the main brachial vein.

The following 3 veins are not strictly veins of the upper extremity but of the thorax. They are however given here as they are the tributaries of the subclavian vein.

(4) *The Sternal vein*: collects blood from the sternum and its muscles and runs anteriorly to join the subclavian at right angles to it just after the junction of the brachial.

(5) *The Pectoral*: is a long vein draining the superficial veins of the thorax as well as the anterior abdominal wall, and runs obliquely inwards to fall into the posterior face of the sub-clavian about half its length from its root.

(6) *The Anterior Intercostal*: is also a long vein arising near the diaphragm and receiving branches from the intercostal muscles laterally, and runs anteriorly on the inner wall of the thorax to fall into the subclavian near its base posteriorly.

4. THE VEINS OF THE ABDOMEN, PELVIS AND LOWER EXTREMITY

A. The Posterior Vena Cava.

The abdominal postcaval is single and brings the entire blood from the tail, legs, abdomen and viscera to the right auricle. The origin of this stout median vein is by the junction of the right and left common iliacs. On its way up the postcaval receives the caudal, the iliolumbars, the spermatics (or ovarians), the renals, and the hepatics, after which it penetrates the diaphram and becomes the thoracic postcava.

(1) *The Internal iliac*: of each side is formed by the union of :—

(*i*) the *gluteals*, from the ventral region of the pelvis;

(*ii*) the *rectal*, from the lower rectum;

(*iii*) the *uterine*, from the uterus and vagina in the female or

(*iv*) the *external genital*, from the male genitalia.

The internal iliac is short and does not extend far into the thighs in the squirrel.

(2) *The External iliac*: is a continuation of (i) the *femoral vein* of each leg or hind limb, which is formed by the union of 3 main veins; (ii) the *deep femoral* receiving blood from the popliteal vein at the knee where it runs with the artery of the same name; (iii) the *superficial femoral* vein is the main superficial vein which carries most of the blood from the surface of the thigh, leg and foot, (iv) the *sciatic vein* is a long vein extending from the foot and along the inner side of the thigh where it joins the femoral vein before falling into the external iliac. The sciatic and the superficial femoral form a long characteristic loop by running together at the lower

part of the leg; (v) the *anterior tibial* and the *posterior tibial* are deep veins of the leg which unite in the knee to form the *popliteal vein,* which falls into the deep femoral.

(3) *The Common iliac* : on each side is formed by the union of the external and internal iliacs. Before each common iliac joins its fellow to form the abdominal postcava it receives the posterior parietal, the vesicular and the pelvic veins.

(4) *The Posterior parietal* : is a long superficial vein, arising a little before the forking of the common iliac into the external and internal iliacs, which runs downwards and then anteriorly on the wall of the lower abdomen collecting blood from that region.

(5) *The Vesicular*: is a short vein arising posteriorly from the middle of the common iliac and collecting blood from each half of the bladder.

(6) *The Pelvic*: of each side arises near the vesicular but from its anterior face and runs ventrally to collect blood from the dorsal pelvic region.

(7) *The Caudal*: is single and median and although it appears to arise from the base of the left common iliac, it actually arises from the dorsal face of the posterior-most end of the abdominal postcaval turns upwards and backwards to run into the tail collecting blood from there.

(8) *The Ilio-lumbars* : are a pair of stout veins, arising from the postcaval midway between the renals and the fork of the common iliacs. Each ilio-lumbar runs horizontally at right angles to the postcaval and collects blood by several branches from the muscles of the back and adjacent structures.

(9) *The Spermatic or ovarian*: consist of one pair of veins (the spermatic in the male and ovarian in the female) each arising near the origin of the ilio-lumbar. Each *spermatic* arises ventrally from the junction of the ilio-lumbar with the vena cava; but its origin varies a great deal in different individuals. In some each arises from the base of the ilio-lumbar of its side, while in others it may arise anterior to the ilio-lumbars from the vena cava itself. Each spermatic is a long vein passing ventrally and forming an arc to run posteriorly in the abdominal cavity; and finally emerges out of the abdominal cavity through the inguinal canal into each testis, from which it collects blood by numerous branches. Each *ovarian* is a stout vein much shorter than the spermatic, arising from the vena cava a little anterior to the origin of the ilio-lumbar, and after running horizontally outwards for a little distance runs posteriorly to end in the ovary and fallopian tube of its own side. The origin of the ovarian veins may also show large variations as in the spermatic veins.

(10) *The Renals* : consist of a pair of stout short veins opening into the vena cava almost at right angles, one on each side, and are placed asymmetrically, the right lying more anterior to the left renal opposite each kidney. Each renal receives a small supra-renal from the helium of each suprarenal body and falls into the hilus of each kidney.

(11) *The Hepatics* : drain the liver and are two in number lying on the same side of the posterior vena cava *i.e.* on the left side alone. They lie one behind the other, almost at right angles to the postcaval, and commence in the *intralobular-veins* from the liver lobules which unite to form *sublobular veins,* and these finally join to form each hepatic vein.

B. The Portal Veins.

The portal system includes all the veins which drain the blood from the abdominal part of the digestive tube (with the exception of the lower part of the rectum) and from the spleen, pancreas and gall-bladder. The blood from these veins falls into one portal vein which ramifies like an artery in the liver and ends in capillary vessels called *sinusoids*, from which the blood is collected by the hepatic veins and conveyed to the posterior vena cava. Thus the blood of the portal system has to pass through two sets of capillaries: (1) the capillaries of the digestive tube, spleen, pancreas and gall-bladder, and (2) the sinusoids of the liver. Three main veins—the pancreatic, the gastric and the mesenteric—join and form the *portal vein* which is short in the squirrel and immediately falls into the liver.

(1) *The Pancreatic*: is the first branch joining laterally the portal vein and is formed by the union of an anterior branch, the *pancreatic* and a posterior one the *anterior gastric* supplying the organ or region denoted by the names.

(2) *The Gastric*: is a long stout vein which collects the major part of blood from the stomach through a *median gastric* vein laterally and from the duodenum through the *duodenal* branch posteriorly.

(3) *The Mesenteric*: is the largest of the 3 veins forming the portal vein. Before it branches into the anterior and the posterior mesenteric veins, the mesenteric gives off a long *lienogastric* vein, which is peculiar to the squirrel, and which runs laterally up to the stomach where it receives the short *posterior gastric* (or pyloric) vein. The *splenic* vein, running under the stomach also falls into the Lienogastric near the stomach, a condition peculiar to the squirrel. The mesenteric is formed by union of the anterior and the posterior mesenteric veins.

(4) *The Anterior mesenteric*: is stout and returns the blood from almost the entire small intestine and the caecum through a large number of branches. It does not fall into either the splenic vein or into pyloric as in man and rat respectively, but joins the posterior mesenteric to form a stout mesenteric which receives the lienogastric to fall finally into the hepatic portal.

(5) *The Posterior mesenteric*: is a long thin vein which receives blood from two tributaries—the colic from the colon and the *rectal* from the rectal plexus.

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EFFECT OF NITROGEN SUPPLY ON NUTRIENT UPTAKE AS REVEALED BY LEAF ANALYSIS AND ON THE GROWTH AND YIELD OF *HORDEUM VULGARE* L.

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INTRODUCTORY

Nutrient concentration in plants, as an index of their availability in the soil, has been recognised by a number of workers. According to Duley and Miller (1921), the percentage of nitrogen and potassium in the maize plant was approximately proportional to the supply of the nutrients. Schertz (1929) also found high nitrogen content in leaves of cotton and potato plants when fertilized with a mixture high in nitrogen. Bartholomew and coworkers (1933) reported that the amount of N, P and K absorbed by plants was controlled to a great extent by the concentration of these elements in the nutrient media. Gregory (1937) held that the rate of uptake of all nutrients studied was proportional to external concentration upto the initiation of floral differentiation. Rajagopal and Iyengar (1938) reported that nitrogen and phosphate application consistently increased their content in tissues while potash treatment did not give increases in K concentration. Thomas and Mack (1939, 1940) observed that nutrition intensity and yield were directly correlated. Beeson *et al* (1944) reported that plant composition held a relationship with the makeup of the nutrient medium.

Lagatu and Maume (1930), Thomas (1937), Shear *et al* (1946) and others took '*diagnostic foliare*' as the basis of investigations on plant nutrition problems as they held that foliage characters were the resultant of three factors, viz., the genetical makeup of plants, the climate and the soil. Beauchamp (1942), taking the leaf as an index of soil fertility, concluded that the intensity of nutrients held a direct relationship to soil fertility on the one hand and to crop-yield on the other. Lundegardh (1947) also showed advantages of leaf analysis over soil analysis.

A mass of data exists on the influence of nitrogen application on growth and yield of crop plants. Some of the more important contributions have been those by Ballard and Petrie (1936), Das (1936), Mukerji and Agarwal (1944), Lal and Subba Rao (1952), Singh (1954) etc.

PROCEDURE

Field experiments on the sandy loam soil of the Gangetic alluvium were conducted with barley (*Hordeum vulgare*, *Var.* C 251). Barley was raised in field receiving sulphate of ammonia at five different levels, 35 days after the sowing of the crop, when its growth, yield and uptake was studied. The plan of the experiment was laid out after the simple replicated design, with four blocks each subdivided into six plots to accomodate the treatments: control, 20, 40, 60, 80 and 100 lbs. of N/acre. Five plants were selected at random from each plot and growth of different plant organs was recorded at three stages in its life cycle synchronizing approximately with the physiological stages: tillering,

heading and milky grain falling at 50, 70 and 90 days respectively from the date of sowing. The number and weight of ear per plant, length, spikelet number and number of grains per ear as also absolute weight of grains were ascertained at the time of harvest, along with the yield of grain and straw.

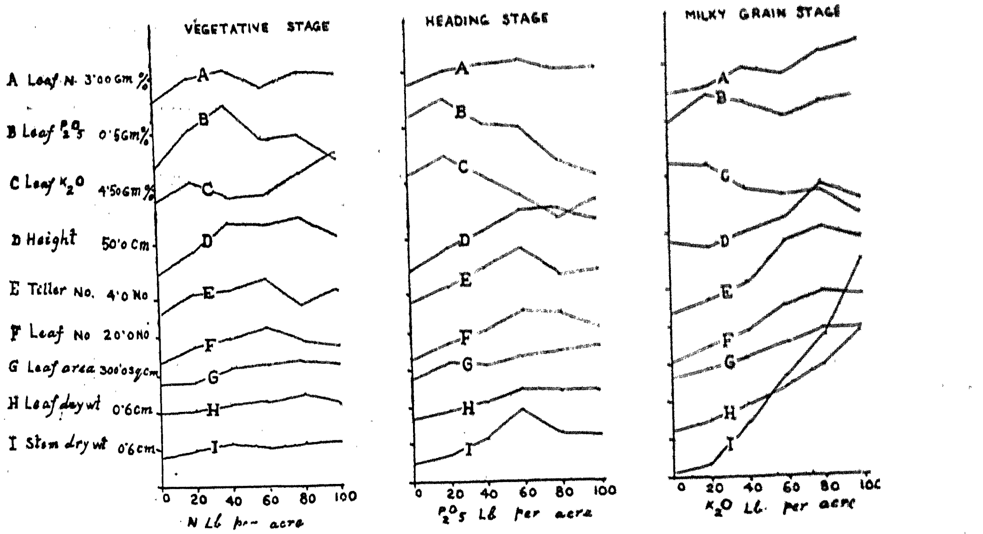
Fully developed, healthy and green leaves of approximately the same age and expansion were collected at each sampling date, washed free of adhesive particles and dried in an oven at 80° C, powdered and stored for use for the determination of nitrogen, phosphorus and potassium.

Nitogen was estimated by the Gunning method (A. O. A. C., 1945); phosphorus by the colorimetric micromethod (A. O. A. C., 1945) and potassium by the cobaltinitrite method (Piper, 1944). Data were statistically analysed. Analysis of variance was done and 'F' test was employed to evaluate the significance in each case.

THE FINDINGS

Linear growth of the barley plant was maximum in 80 N* treatment at all the stages (Fig. 1 D). Increasing and decreasing doses on both sides of 80 N exhibited less response in vertical growth of the plants. Tiller production was seen to be significantly affected at all the three growth stages (Fig. 1 E). Maximum tillering was recorded in 60 N at the vegetative and heading stages but at the milky grain stage the maximum was held by 80 N and significantly so. Leaf number showed a significant rise over the control upto 60 N at the vegetative and heading stages and upto 80 N at the milky grain stage but doses beyond this recorded a decline (Fig. 1 F). Foliage expansion of the plant was maximum in 80 N treatment at the vegetative stage, but at the heading and milky grain stages maximum was attained by the top dose of 100 N although the increase in 100 N as compared to 80 N was insignificant (Fig. 1 G). At the milky grain stage, the increase in leaf area was gradual with increase in dosage.

FIG. 1- NITROGEN EFFECT ON GROWTH AND LEAF COMPOSITION OF BARLEY AT DIFFERENT PHYSIOLOGICAL STAGES



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*20 N, 40 N, 60 N, 80 N and 100 N stand for 20, 40, 60, 80 and 100 lbs. of nitrogen per acre respectively.

Growth as measured by dry weight of the leaves had been best attained by 80 N at the vegetative stage of the plant (Fig. 1 H). At the heading stage 60 N had maximum values, although the increase was insignificant over that of 80 N. Highly significant maximum leaf weight was recorded at the milky grain stage by 100 N treatment. Stem dry matter was maximum in 80, 60 and 100 N treatments at the vegetative, heading and milky grain stages respectively (Fig. 1 I). A gradual increase over the control upto 100 N was also noticed at the milky grain stage.

TABLE I

The Effect of Nitrogen Dressing on the Ear Characters of Barley

Characters	NITROGEN LBS./ACRE 0	20	40	60	80	100	S. E.	C. D. 5%	C. D. 1%
Ears/plant (No.)	2·55	2·75	4·00	4·60	4·45	4·05	0·111	0·334	0·463
Ear weight (gram/plant)	3·29	3·76	6·26	6·64	8·09	8·16	0·224	0·675	0·933
Ear length (cm.)	15·93	16·34	17·07	17·05	18·05	18·05	0·227	0·684	0·946
Spikelet No. (per ear)	10·91	11·48	13·60	13·24	15·05	15·30	0·155	0·467	0·646
Grain No./ear	26·25	27·49	32·38	31·50	39·15	41·39	0·609	1·835	2·538
Grain weight (absolute, gm.)	41·32	40·01	41·36	42·37	43·89	42·59	0·561	1·690	2·338

TABLE II

Grain and Straw Yield of Barley as affected by Nitrogen Dressings (Lbs./Acre)

Yield	NITROGEN LBS./ACRE 0	20	40	60	80	100	S. E.	C. D. 5%	C. D. 1%
Grain	526·55	844·82	932·08	1000·00	1099·72	1242·50	77·49	233·50	322·91
Straw	1738·06	1912·28	2031·18	2099·57	2503·73	2837·61	129·12	389·07	538·05
Straw/grain	3·30	2·26	2·18	2·09	2·27	2·27	...	...	...

Ear-number per plant increased over control for each treatment upto 60 N after which a fall was registered (Table I). Weight of ears per plant increased with increasing doses of nitrogen. Ear length also increased with increase in nitrogen application upto 80 N. The development of the ear as indicated by the spikelet number showed a gradual increase with the exception of 60 N which registered a decline as against 40 N. The number of grains produced per ear did not show significant rise in 20 N over control but increases in 80 and 100 N were highly significant. All the treatments except 20 N showed an increase in absolute weight of grains.

Grain yield as affected by nitrogen treatments was maximum in the highest dose of 100 N, while least in the control (Table II). With increase in nitrogen treatment a gradual increase was recorded in grain production. Straw yield increased with increasing doses of nitrogen. There was a gradual and steady increase over the control upto 60 N level which was accentuated by 80 and 100 N that recorded a very abrupt and significant increase in straw production.

TABLE III

Leaf Composition at different Physiological Stages of Growth of the Barley Plant (oven dry basis)

Growth stages	NITROGEN LBS./ACRE 0	20	40	60	80	100	S. E.	C. D. 5%	C. D. 1%
				NITROGEN(N)					
Vegetative	2·950	3·550	3·750	3·202	3·650	3·550	0·113	0·341	0·472
Heading	3·625	3·975	4·200	3·325	3·950	4·050	0·083	0·252	0·349
Milky grain	3·220	3·400	3·900	3·750	4·350	4·650	0·152	0·459	0·635
				PHOSPHORUS (P_2O_5)					
Vegetative	0·3968	0·5193	0·5877	0·4800	0·4925	0·4364	0·0152	0·0488	0·0675
Heading	0·6323	0·7346	0·6595	0·6525	0·5598	0·5279	0·0234	0·0765	0·0995
Milky grain	0·5473	0·6296	0·6091	0·5610	0·5994	0·6049	0·0279	0·0839	0·1161
				POTASSIUM (K_2O)					
Vegetative	4·285	4·747	4·292	4·326	4·890	5·477	0·187	0·565	0·782
Heading	4·790	5·357	4·717	4·206	3·646	4·047	0·151	0·456	0·632
Milky grain	3·420	3·384	2·701	2·544	2·755	2·041	0·140	0·421	0·583

The uptake of nitrogen as revealed by the leaf nitrogen percentage was maximum in 40 N and minimum in no treatment at the vegetative stage (Table III). Nitrogen applied at the rate of 60 lb. per acre showed an increase over control though, insignificantly while rest of the treatments had significantly higher nitrogen percentage. At this stage a continuous increase was recorded over the control upto 60 N but higher doses showed a decline. As against the heading stage, there was a decrease in leaf nitrogen at the milky grain stage in all the treatments except 80 and 100 N which showed considerable rise. At this stage there was a gradual increase over the control upto 100 N treatment except 60 N which recorded a significant fall as compared to higher treatments,

The amount of phosphoric acid taken up by the plants at the vegetative stage was maximum in 40 N treatment, heavier and lighter doses, on the contrary, had significantly low values (Table III). With increase in age of the plants upto the heading stage, an increased percentage of P_2O_5 in the leaves of all the treatments was noted. A very significant increase was seen in control and 20 N level but further nitrogen treatments upto 100 N showed a gradual fall in P_2O_5 values in leaves at the heading stage. Finally, at the milky grain stage 20 N, again, had maximum value and the control the minimum. From 20 N to 60 N, there was a regular fall in phosphoric acid values and again an increase in 80 and 100 N was recorded.

The uptake of potash at the vegetative stage under the 20 N treatment exhibited an increase over the control though insignificant (Table III). There was no significant difference amongst control, 20, 40 and 60 N treatments in potash uptake. The increases in 80 and 100 N were significantly high. At the heading stage, significantly highest value was recorded by the 20 N treatment, while the

rest registered but lower values, there being a significant and regular fall from 20 N to 80 N treatments. At the milky grain stage control and 20 N had significantly higher potash values that rest of the treatments, although a gradual fall compared to control upto 60 N treatment was noticed.

DISCUSSION

Nitrogen, evidently, played a positive and significant role in influencing most of the plant characters studied. The effect of all nitrogen applications was well marked in-so-far as, morphological characters, such as tiller and leaf number and stem dry weight were influenced to a lesser extent at the 50 day stage than the rest of the characters studied (*cf* Fig. 1 E, F and I). On an average tiller number, leaf number, leaf area, leaf dry weight and stem dry weight showed higher utility at heavier doses at the 90 day stage than at earlier stages (*cf* Fig. 1 E to I). The decrease in the tiller number and leaf number at the 90 day stage in the lower treatments (control, 20, 40, and 60 N) was, probably, due to drying of the non-ear bearing tillers and leaves but no corresponding decrease in leaf area was observed. The leaf/stem ratio indicated that upto 50 days there was almost similar effect of age on both the components of the plant, but with further advance in age, the ratio depleted rather considerably indicating greater and more rapid stem production as against leaves. The leaf nitrogen percentage was relatively high in the higher nitrogen treatments at the milky grain stage of analysis (Fig. 1 A). It indicated that upto heading stage higher doses of nitrogen led to a slowing down in the rate of uptake of nitrogen by the plants, coupled with a fall in the growth rate. Lal and Subba Rao (1952) studying the effect of N, P. and K. also found that both age and treatment had highly significant effect on all the growth characters.

There was a highly significant positive correlation between leaf number and tillering with all the doses used, at all the stages. This similarity was associated with the meristematic activity of the plant indicating thereby that the formation of leaf and stem primordia go hand in hand. Increased nitrogen addition led to increased meristematic activity of the plant and an increase in both leaf and stem dry matter. Working with corn, barley, wheat and rye Gracanin (1932) also found that with increase in the nutrient medium, there was an increase in the curve of growth for aerial organs. Crowther (1935) stated that one of the main functions of nitrogen was the initiation of meristematic activity. Singh (1941) also reported beneficial effects of nitrogen application on growth of sugar cane. The increase in leaf area provided a larger surface for photosynthesis.

Tiller number and stem dry weight (*cf.* Fig. 1 E and I) on the one hand and leaf number and leaf dry weight (*cf.* Fig. 1 F and H) on the other also exhibited a correlation at the heading and milky grain stages with minor fluctuations. At the final stage of growth records, when plants were in the milky grain stage a correlation was observed between the height of plants and tiller number. A similar trend was also observed in leaf number and leaf area under all the treatments. The leaf weight and stem weight (*cf.* Fig. 1 H and I) at the final stage of growth had also clear-cut correlation. With increase in leaf weight there was also an increase in stem weight, while a decrease in leaf weight was associated with a decrease in stem weight in all the treatments. It may, thus, be assumed that the leaf production, because of being the centre of metabolic activities, controlled the dry matter accumulation in stem.

In regard to decrease in the number of ears in the higher doses of 80 and 100 N respectively, it seems, that the energy was utilized in the production of healthier ears as evidenced by increase in ear weight. The straw/grain ratio showed that

comparatively more of nitrogen was utilized upto 50 lbs in the grain production. Higher doses of 80 and 100 N levels proved useful in increasing both grain and straw yields and more so of straw.

Leaf area at the vegetative stage was found to have a positive correlation with ear number indicating that increase in leaf area favoured ear development. The results also indicated that the final grain yield depended to a large extent on the total leaf area because increase in leaf area at the milky grain stage was associated with a corresponding increase in grain yield.

The nitrogen percentage in the leaves of plants, which to a great extent controls most of the physiological processes, increased with an increase in nitrogen supply. The low value of nitrogen in 60 N at the vegetative stage was probably due to an increase in vegetative growth (Fig. 1 A), especially in tiller and leaf number. This lead to a decrease in the amount of nitrogen on unit weight basis. Leaf P_2O_5 also exhibited an increase during this stage (Fig. 1 B) which also behaved in a way similar to nitrogen as had been pointed by Richards and Templeman (1936). At the milky grain stage the leaf nitrogen percentage had decreased as compared to heading stage in control, 20 and 40 N treatments. This decrease in leaf nitrogen seemed to be due to transference of nitrogen from leaf to other organs especially to growing ears.

Phosphoric acid uptake showed an increase at lower doses of 20 and 40 N but with more of nitrogen application there was no corresponding increase in the amount of phosphate per unit weight of leaf material (Fig1 B). The decrease may be attributed partly to an increase in vegetative growth and partly to insufficient phosphate to cope with the increased demand of the nitrogen fed plants. For phosphate accumulation in the leaves of lower nitrogen doses (upto 40 N in the early vegetative stage and 20 N in the later stage) proved more efficacious, indicating thereby, that the application of nitrogen was helpful to phosphate uptake, especially in the lower dosage at earlier stages. This fact was further supported by increased values of both N and P in the leaf. An indication to this effect was also evident in the higher treatments at the milky grain stage.

Leaf phosphorus showed a marked increase at the heading stage over both the vegetative and milky grain stages. This increase seemed to suggest that with advance in age of the plants, phosphorus taken up by the roots and held there, if in excess, apart from the amount transferred to the actively growing regions, was translocated to the leaves to meet the impending demand at the heading stage of the ears. Leaf P_2O_5 at the milky grain stage was found to have slight correlation with straw yield as there was some similarity in between the leaf phosphorus and straw yield curves.

There was ample evidence to show that the application of nitrogen increased the uptake of potash by the plants. The fall in leaf potash (Fig. 1 C) at 40 and 60 N levels as compared to 20 N at the vegetative stage seemed to be due to volume increase in these treatments as shown by the growth curves (Fig. 1). There was reduction in the amount of potash on unit leaf weight basis though not due to a decrease in uptake of potash from the soil. The high value of potash at 80 and 100 N levels could be attributed to restricted growth in these treatments when flooding of the tissues with potash was evident.

The high value of potash in 20 N and control at the heading stage was due to limited growth of the plants. The fall in the amount of leaf potash (Fig. 1 C) in 40, 60 & 80 N was probably due to two causes—(1) the increased growth of the tops, and (2) the distribution of potassium in different organs, for, as Lundegardh (1932)

held : the total amount of potassium might have been distributed in plants in such a manner that the majority portion was always stored in the stem. At the vegetative stage most of the potassium taken up by the plant was stored up in the leaves, while at heading most of the potash was being utilized by the stem leading to a fall in the amount of potash in 40, 60 & 80 N treatments. At the milky grain stage a fall was observed in all the treatments as compared to heading and vegetative stages and it seemed that the translocation of potash from leaf to other parts had started (Table III).

The two stages of observations i. e., vegetative and heading depicted a marked similarity in the trend of results (Fig.1) while the milky grain stage exhibited a different response both in extent and nature. Does it indicate the existence of a phase in between the heading and milky grain stages, when the part played by the nitrogen in the metabolic activities of the plant takes some different course? This stage may coincide with the fertilization of the ovary leading to the commencement of seed setting. This aspect, however, needs further investigation.

SUMMARY

1. The effect of nitrogen applied in the form of sulphate of ammonia on barley (*Hordeum vulgare, Var.* C. 251) grown on the sandy loam soil under field conditions was studied in a statistically laid out plan and the data were subjected to statistical analysis.

2. Fertilizer was applied at five different levels viz., 20, 40, 60, 80 and 100 lbs., of nitrogen per acre.

3. Periodical records were taken to asses the extent of growth, ear characters and final yield. The quality of the produce was also assessed at the vegetative, heading and milky grain stages by leaf analysis method when other records were also taken. Leaves were analysed for nitrogen, phosphorus and potassium.

4. Most of the plant characters showed higher utility of the applied nitrogen at heavier doses at the 90 day stage than at earlier stages.

5. Many growth characters showed positive correlations.

6. Leaf nitrogen and leaf phosphorus also showed positive correlation.

7. The response of nitrogen application, on growth and nutrient uptake at different stages and the final yield, has been explained in detail on the basis of leaf composition.

8. The effect of the nitrogen application could be distinguished into two different categories, characterised by the age of the plants.

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THORACIC SCLERITES AND APPENDAGES OF THE IMAGO OF *LEUCINODES ORBONALIS* GUEN. (LEPIDOPTERA, PYRAUSTIDAE)

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INTRODUCTION

There has been a striking dearth of papers dealing with the external morphology of the adult lepidopterous thorax. Most of the work done upto the early part of this century is incomplete or confusing due to different terminology used by different workers. In 1927 Snodgrass gave an excellent generalized description of the thoracic morphology of insects and all the later work has been based on this description. Shephard (1930) was the first to give a comprehensive and fairly accurate comparative account of the pleural and sternal sclerites in *Melittia satyriniformus* (Aegenidae) and *Catoeala concunbens* (Noctuidae). Later, Madden (1944) gave a detailed description of the external morphology of the adult tobacco horn worm *Protoparce sexta* (Sphingidae) and following the same plan Freeman (1947) studied the morphology of *Archips fumiferana* (Tortricidae). It is evident that no description exists of the thoracic sclerites of any representative of Pyraloidea which forms a very important group of the Lepidoptera. The present work has been undertaken with a view to fill in this lacuna.

MATERIAL AND TECHNIQUE

The moths were reared in the laboratory from the brinja's infected with the larvae. Newly emerged imagos were killed in hot water, their different parts were separated and treated with KOH. Since boiling the insects or their parts in KOH often resulted in the loss of certain delicate parts and lead to the darkening of the chitinous portions, they were usually left overnight in 10% KOH solution at a temperature of 58° to 60°C. This method dissolved all the muscles without dissolving the feebly chitinized or membranous portions. After thoroughly washing the material to remove all traces of KOH it was dehydrated, stained and mounted.

OBSERVATIONS

The Cervix

The major part of the cervix is membranous because it is actually the intersegmental region lying between the head and the thorax. The cervical sclerites which are very prominent in other insects are much reduced here, being present in the form of a pair of Y-shaped sclerites the lateral cervical sclerites (Fig. 3). The portion representing the stem of Y is articulated to the anterior margin of prothoracic episternum and is prolonged beyond the point of articulation. The two arms

of Y articulate with the ventral margin of the post occipital sclerite. The posterior apices of the lateral cervical sclerites lie dorsal to the anterior edge of the episternum of the prothorax.

The Tergites

Pronotum.—The pronotum is formed of three small, partly fused pieces arranged to constitute a Y-shaped structure (Fig. 2). The proximal portion of the posterior piece of the stem of Y is articulated to the anterior margin of the mesothoracic prescutum. The arms of Y or the anterior apices are curved around the dorsal portion of the anterior opening into the thorax and ventrally they are articulated with the episternal sclerite. Two flattened membranous lobes known as patagia lie dorsally to the anterior arms of the pronotum.

Mesotergum—The mesotergum (Fig 1 & 2) consists of all the four sclerites i.e. prescutum, scutum, scutellum and postscutellum which are distinctly separated from one another by well marked sutures.

The prescutum (Fig. 2) is a narrow strap like sclerite lying hidden in a deep semicircular cleft in the anterior margin of the scutum. Hence it cannot be seen in its entirely dorsal side. The prescutal suture which marks the boundary between this sclerite and the scutum in other Lepidoptera is very feebly developed in *L. orbonalis*.

The scutum (Fig. 1) is the most prominent sclerite of the thorax. From the dorsal view it appears somewhat hexagonal and convex. Posteriorly, it is separated from the scutellum by a prominent scutoscutellar suture while its interior margin which bears the prescutum is notched in the middle. Each lateral margin is produced into a suralare or anterior notal process to which the fore wings are articulated. It acts as the anterior fulcrum for the movement of the fore wing. The antero-lateral margin of the suralare is covered over by a lunate large tegula which extends dorso-laterally over the anterior portion of the scutum. The ventral margin extends behind beneath the base of the fore wing. The sub-tegula is in the form of an irregularly shaped sclerite and is placed anteriorly to the suralare. A little posterior to the suralare the lateral margins of the scutum are produced into a lobular projection, the adnotale, which is articulated with the first axillary wing sclerite. Posterior to the adnotale the lateral margin of the scutum is thrown into two tubular projections of which the anterior one or the adanale is longer than the posterior one or the postadanale which is also more curved than the former. The adanale articulates with the proximal end of the third wing axillary. Between the adnotale and the posterior margin of the suralare there is a deep notal incision in the lateral margin of the scutum. There is no trace of a median ridge or suture on the scutum as reported by Snodgrass (1927) and Madden (1944).

The scutellum (Fig. 1) is a convex sclerite attached posteriorly to the scutum. It is separated from the former by a prominent scutoscutellar suture which forms a V-shaped ridge internally. It is a rhomboidal sclerite whose lateral margins extend into a membranous axillary cord running outwards along the postadanale and become continuous with the anal region of the forewing.

The postscutellum (Fig. 1) is a narrow sclerite which surrounds the convex posterior margin of the scutellum. Because of its narrowness and the extreme development of the mesothoracic scutellum and the metathoracic scutum, it remains partly concealed between the two. The intersegmental membrane between the meso and metathoracic tergal sclerites forms a large backward and inwardly projecting sclerotic structure, the postphragma which is spatula-like in shape. The inward

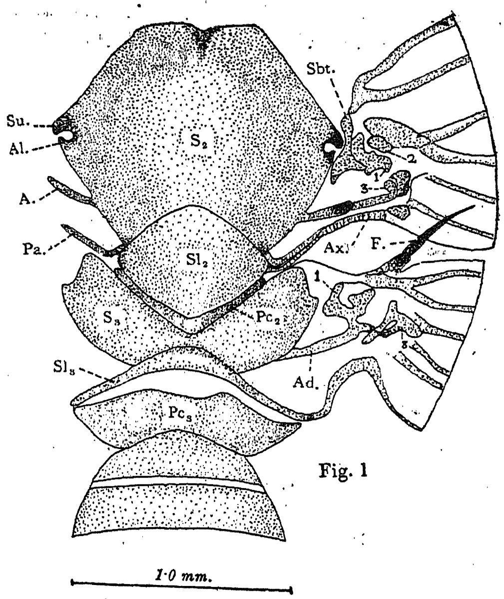


Fig. 1. Dorsal aspect of the thorax.

A., mesothoracic adanale; Ad., metathoracic adanale; Al., adnotale; Ax., axillary cord; F., frenulum; Pa., postadanale; Pc_2, mesothoracic postscutellum; Pc_3, metathoracic postscutellum; S_2, mesoscutum; S_3, metascutum; Sbt., subtegula; Sl_2, mesothoracic scutellum; Sl_3, metathoracic scutellum; Su., suralare.

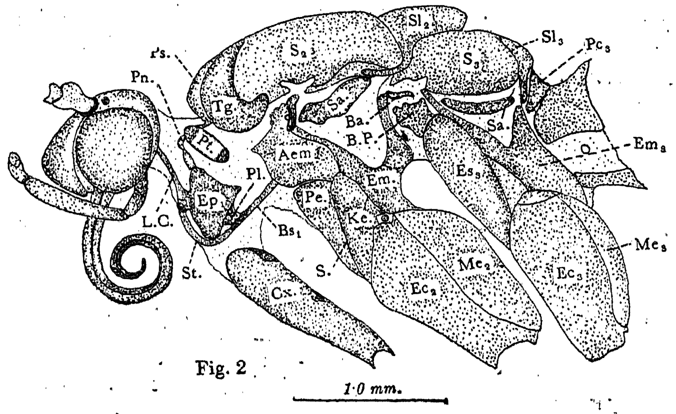


Fig. 2. Lateral aspect of the head and thorax.

Aem., anepisternum; Ba., Basalare; B. P., basalare pad; Bs_1, prothoracic basisternum; Cx., coxa; Ec_2, mesothoracic eucoxa; Ec_3, metathoracic eucoxa; Em., mesothoracic epimeron; Em_3, metathoracic epimeron; Ep_1, episternum; Es_2, metathoracic episternum; Ke., katepisternum; L. C., lateral cervical sclerite; Me_2, mesothoracic meron; Me_3, metathoracic meron; Pc_3, metathoracic postscutellum; Pe., preepisternum; Pl., pleuron; Pn., pronotum; Ps., prescutum; Pt., ptagium; S., preepisternal suture; S_2, mesoscutum; S_3, metascutum; Sa., subalare; Sl_2, mesothoracic scutellum; Sl_3, metathoracic scutellum; St., sternum; Tg., tegula.

development of the postphragma isso extensive that the dorsal blood vessel and the alimentary canal are forced into the ventral region of the thorax in order to pass beneath it.

Metatergum

The metatergum is formed of the scutum, scutellum and postscutellum (Fig. 1). The metathoracic prescutum is absent in this Pyraustid.

The scutum (Fig. 1) consists of two lateral prominent lobe-like sclerites which surround the mesotergum basally. Its anterior lateral margins are produced to form a suralare and the posterior lateral margins extend into long narrow adanales. The anterior projection or the suralare forms the pivot point for the articulation of the hind wing with the first axillary.

The scutellum (Fig. 1) is very much reduced as compared with the mesothoracic one. It is a narrow, transverse, band-like, crescent shaped sclerite overlying the posterior part of the metathoracic scutum. Its lateral margins are produced into the membranous axillary cord extending upto the anal region of the hind wing.

The postscutellum (Fig. 1) lies immediately behind the metathoracic scutellum. As in the case of the mesothorax, here also this sclerite lies in a deep invagination and forms an internal phragma on which a number of muscles are attached.

The pleurites

The terminology of the pleuron is particularly confusing. It offers more difficult problem of morphology than does either the tergum or the sternum because of the division and subdivision of pleuron into a number of sclerites.

Mesopleuron

The pleural suture divides the mesopleuron (Fig. 2) vertically into an anterior portion, the episternum and a posterior portion, the epimeron. Two sutures, one horizontal and the other transverse, divide the episternum into three sclerites. The curved pre-episternal suture divides the episternum horizontally into a largely membranous area the preepisternum and the katepisternum. The transverse one or the anepistonal suture seems more like an open membranous cleft extending to the margin of the epimeron to nearly three-fourth of the distance of the pleural suture, its posteior part being visible as an indistinct suture which extends to the pleural suture. The anepistonal suture divides the episternum into a dorsal anepisternum and a ventral katepisternum.

The epimeron is V-shaped. Its anterior arm reaches up to the pleural wing process and the posterior arm upto the postadanale. The preepimeron which has been reported by Shephard (1930) in other Lepidoptera is absent in *L. orbonalis*.

There is a prominent irregular sclerotised plate situated in the membrane above the epimeron. Crampton (1914) termed it as subalare.

Metapleuron

Much like the mesopleuron, the metapleuron (Fig. 2) is divided vertically by a suture into the anterior episternum and the posterior epimeron. The episternum is continued ventrally to the basisternum (Fig. 3) and at its anterior dorsal margin it bears a small convex sclerite, the basalare pad. Between the antero-ventral margin of the mesothoracic epimeron and the dorsal margin of the basalare pad lies a narrow, elongated sclerite the subalare. The anterior arm of the episternum is extended into a long pleural wing process. The narrow, oblong subalare lies in the membrane between the metathoracic scutum and the V-shaped metathoracic epimeron.

THE STERNITES

Prosternum.—The episternum (Fig. 3) is a small convex sclerite. Its dorsal apex is articulated to the ventral margin of the pronotum and the ventral posterior margin with the pleuron. The anterior midventral part of the pleuron articulates with the posterior part of the sternum. The episternum is fused on both of its anterolateral margins with two narrow strap like sclerites—the precoxales (Fig. 3). The basisternum (Fig 3) is much reduced and narrow. It is bifurcated posteriorly. Its anterior ends articulates with the posterior margins of the pleuron while the posterior bifurcate arms with the anterior edge of the spinasternum which is also bifurcated anteriorly. The spinasternum (Fig. 3) is a narrow sclerite which is forked basally also into two arms which touch the anterior margins of the mesothoracic basisternum.

Mesosternum.—The basisternum (Fig. 3) is fairly large and triangular sclerite. It is invaginated longitudinally in the midventral region to form a prominent suture forming a ridge internally. The furcasternum is in the form of two very narrow highly chitinised sclerites which arise from the posterior margin of the basisternum. They extend to the inner edge of the coxae where they are invaginated to form a pair of strongly chitinised arms. These arms extend inwardly into the cavity of the thorax and unite with the endoskleton. The structure thus formed gives support and rigidity to the thoracic region acting against its buckling or distortion.

Metasternum.—In case of metasternum (Fig. 3) the basisternum and the furcasternum are much reduced as compared to that of the mesothorax. The triangular basisternum is invaginated longitudinally to form a mid-ventral suture and is produced inwardly into a keel like ridge. As in the mesothorax, the posterior part of the basisternum is produced caudally to form the furcasternum. The apices of the furcasternum articulate with the inner face of the eucoxa. The apophysis arising from the furcasternum extend dorsally to form the furcal arms and then continue laterally towards the posterior margin of the metathoracic epimeron.

THE THORACIC APPENDAGES

Wings.—The wings are articulated to the thorax by means of membranes provided with three irregularly shaped axillary sclerites. The humeral plate articulates with the costa of the forewing. The sclerites for articulation are similar to those in the hind wing except that the humeral plate is absent. The humeral angle of the hind wing is provided with a stout forwardly directed frenulum. It consists of alarge spine extending along the underside of the forewing. The venation of the fore and the hindwing has been shown in Figs. 4 & 5 and is based upon Comstock-Needham system.

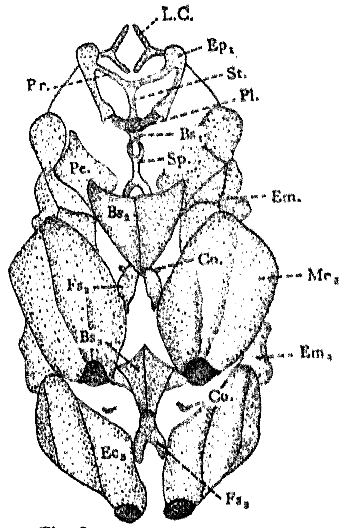


Fig. 3

Fig. 3. Ventral aspect of the thorax.

Bs_1, prothoracic basisternum ; Bs_2, mesothoracic episternum ; Bs_3, metathoracic basisternum ; Co., condyle ; Ec_3, metathoracic eucoxa ; Em., mesothoracic epimeron; Em_3, metathoracic epimeron ; Ep_1, episternum ; Fs_2, mesothoracic furcasternum; Fs_3, metathoracic furcasternum ; L. C., lateral cervical sclerites ; Me_2, mesothoracic meron ; Pe., preepisternum ; Pl., pleuron ; Pr., precoxale ; Sp., spinasternum ; St., sternum.

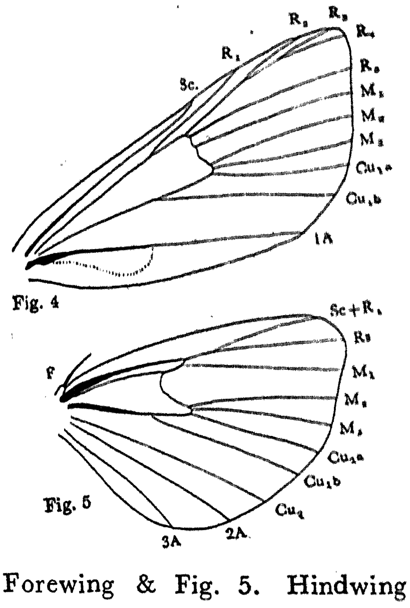


Fig. 4-5 ; Fig. 4. Forewing & Fig. 5. Hindwing showing the venation F., frenulum.

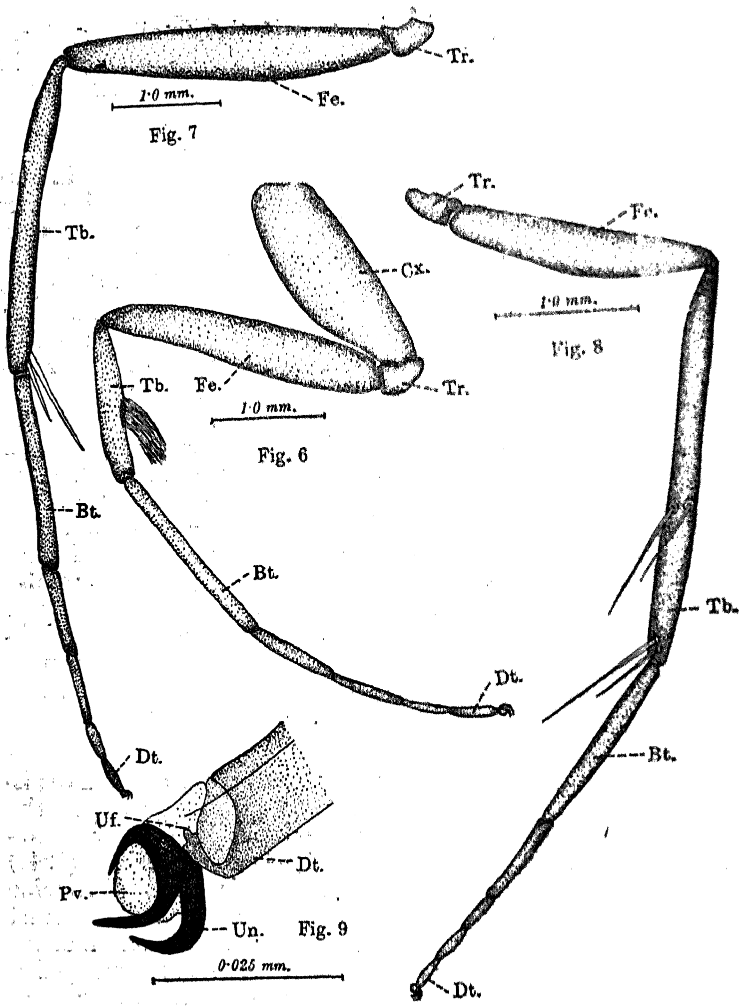
Leg.—Of three pairs of leg, the prothoracic one is the smallest and the metathoracic one is the largest of all. Basically all the three legs (Figs. 6 to 9) consist of the same parts i. e. coxa, thochanter, femur, tibia and tarsi although these differ to some extent in shape and structure.

Coxa.—The coxae of the three pairs of legs differ from one another both in size and shape. The prothoracic coxa (Fig. 6) is elongated and cylindrical being broadest near the base and curving along the anterior margin like an arch, thus forming a narrower distal apex. The meso and meta thoracic coxae (Fig. 2) are truncated cone-like structures being broadest near the middle. The coxa of the prothoracic leg is movable while those of meso and meta thoracic ones are immovable being more or less firmly attached to the basal margin of their respective sterna. The anterior margin of the base of the mesothoracic coxa is attached to the base of the katepisternum and the posterior basal portion to the caudal margin of the mesoepimeron. In the case of the metathoracic coxa, the anterior portion of the base is attached to the basal margin of the episternum and the posterior basal portion to the basal margin of the epimeron of the same segment. Besides, the meso and meta thoracic coxae have their points of articulation on their inner faces with the apices of the furcasternum. The prothoracic coxa is characteristic, since it consists of a single piece unlike those of the meso and metathoraic ones which are divided longitudinally by a basicostal suture into an anterior eucoxa and a posterior meron. They are also strengthened by internal ridges in addition to the basicostal ridge. Possibly these ridges represent the invaginations of the coxal wall in order to function as an additional support and to add rigidity to this structure. Distally the coxae of each of the three legs articulate with two condyles of the respective trochanter, thus making a strong hinge joint.

A minute roughly triangular plate-like structure exists between the katepisternum and the meron of the mesothoracic coxa (Fig. 10) and is separated from the eucoxa by a suture. This sclerite has been termed by Snodgrass (1927) as trochantin and by Shephard (1930) as epicoxal plate. Madden (1944) and Freeman (1947) have also reported the occurance of such a sclerite in Sphingidae and Torticidae respectively. On the anterior side of this triangular plate there is a peculiar round plate-like structure, the anterior margin of which touches the posterior margin of the mesothoracic katepisternum. On this circular plate six minute holes are arranged in a circle (Fig. 11). The position and the structure of this organ resembles those of the plate organs of aphids (Snodgrass, 1935) and other insects and hence I am inclined to regard these also as the sensilla placodea and consider them to be olfactory in function. The six minute holes (Fig. 11) appear to be the distal ends of the vacuolated enveloping cells which contain the terminal strand of the sense cell. Imms (1948) has reported the presence of tympanal organs on the metathorax of Geometridae. No one has, however, reported the oocurance of placoid sensilla of the mesothorax of Lepidoptera.

Trochanter.—The trochanters of all the legs are articulating with the base of the coxae and are in the form of irregular rings. Though it is a small segment but it forms an important hinge of the leg, being more or less firmly fixed to the base of the femur. Like the coxa, it has a strongly developed basicostal ridge bearing the coxal articulation. Its movement is restricted in a vertical plane.

Femur—The size of the femur varies in different legs. The prothoracic and metathoracic femurs are subequal in length. The width in all the three is nearly the same. The femurs of all the three legs possess slightly convex posterior margins.



Figs. 6-9; Fig. 6. Prothoracic leg; Fig. 7. Mesothoracic leg; Fig. 8. Metathoracic leg; Fig. 9. Prothoracic distitarsus showing the ungues and the pulvilus.

Bt., basitarsus: Cx., coxa; Dt., distitarsus; Fe., femur; Pv., pulvilus; Tb., tibia; Tr., trochanter; Uf., unguifer; Un., ungues.

Figs. 10-11; Fig. 10. A portion of the mesothoracic leg showing the position of the epicoxal plate; Fig. 11. Epicoxal plate and the placoid sensilla under higher magnification.

Ec_2, mesothoracic eucoxa; Em., mesothoracic epimeron; Ep. P., epicoxal plate; Ke., Katepisternum; Me_2, mesothoracic meron; Pe., preepisternum; Pl. S. placoid sensilla; S, preepisternal suture.

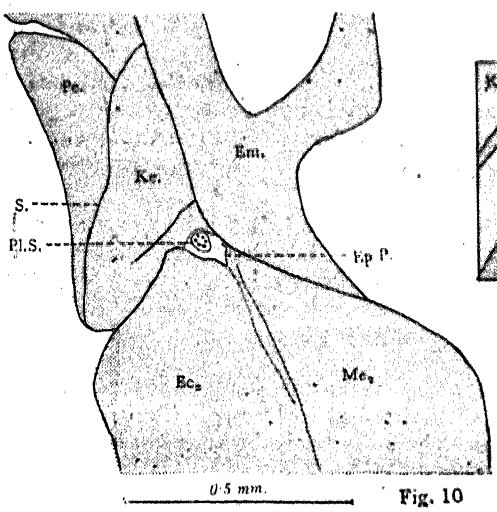


Fig. 10

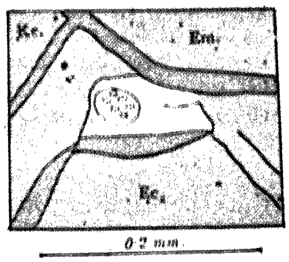


Fig. 11

The anterior margin of the prothoracic one is convex while those of the meso and metathorax have comparatively straight margins. Distally the femur articulates with the tibia.

Tibia.—The tibia of all the three legs differ in length.

The prothoracic tibia (Fig. 6) is short and stout. The width is maximum near about the middle where the inner margin is more convex. A little below the centre on the inner margin the prothoracic tibia bears a somewhat strong and prominent, pointed brush-like process known as the epiphysis.

The mesothoracic tibia (Fig. 7) is clavate in shape and gradually increases in width towards the distal end where it bears a pair of apical spurs on the inner margin, the outer one of which is longer being about twice the length of the smaller one.

The metathoracic tibia (Fig. 8) is the longest and is tubular in shape, the width being maximum at the distal end. It bears two pairs of spurs, an apical pair as on the tibia of mesothoracic leg and another pair below the middle of the inner margin. The longer spines in both the pairs are nearly double in length to the smaller ones and are located on the inner side of the limb. The metathoracic tibia is slightly bent inwards.

Tarsus—The tarsi (Figs. 6 to 8) of each leg consists of five segments. The first segment or basitarsus is the largest in all the three legs and is about equal in length to the total length of the apical four. The terminal segments become progressively smaller and the fifth segment or distetarsus is the smallest in all the three legs.

The basitersus has maximum length in the mesothoracic leg and minimum in the metathoracic one, while the second segment is longest in the metathoracic and the smallest in the prothoracic leg. The third and the fourth segment have aproximately the same length and width in all the three legs. All the four segments of the tarsi are broader near the basal end in all the legs. In case of the fifth segment or the distetarsus the dimensions are approximately the same but the width is maximum at its distal end which bears a pretarsus in each leg. On the membranous bass of the pretarsus (Fig. 9) are supported two prominent, dark brown, curved, hollow movable claws or ungues which are articulated to the median process of the distetarsus or the unguifer. Resting on the bases of the two claws and lying between them is a prominent pulvilus.

SUMMARY

The cervix is largely membranous and has only a pair of Y-shaped lateral cervical sclerites.

The prothorax is reduced and membranous. The pronotum is Y-shaped and the prosternum is divided into episternum, basisternum and spinasternum.

The mesothorax is most specialized. The mesotergum consists of prescutum, scutum, scutellum and postscutellum. While the mesopleuron is divided into anipisternum, preepisternum, katepisternum, epimeron and a subalare. The mesosternum is represented by basisternum and furcasternum.

The metathoracic tergum consists of scutum, scutellum and post-scutellum. The metapleuron is divided into episternum, epimeron and sabalare while metasternum consists of basisternum and furcasternum.

The wing venation is characteristic of Pyraustidae. The prothoracic coxa is movable while meso and metathoracic coxae are immovably attached and are divided by a suture into eucoxa and meron. The epicoxal plate bears a placoid sensilla. Each leg consists of femur, tibia, 5 jointed tarsai and a pretarsus bearing a pair of claws and pulvilus.

ACKNOWLEDGEMENT

The work was carried out in the Zoological Research Laboratories of Allahabad University. The author is extremely grateful to Mr. S. C. Verma and Dr. U. S. Srivastava for taking keen interest in the supervision of this work. Thanks are also due to the authorities of the University and the Government of India for the award of the Senior Research Scholarship and to the Head of the Zoology Department for providing the necessary laboratory facilities.

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FURTHER STUDIES ON BIOMETRY OF UREDOSPORES OF *PUCCINIA PENNISETI* ZIMM.

By

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INTRODUCTION

Basu Chaudhary and Sinha (1955) reported physiologic specialization in *Puccinia penniseti* Zimm. causing the rust disease of *bajra* (*Pennisetum typhoides* Stapf. and Hubb.) and noted slight differences in reactions. Levine (1923 and 1928) indicated that biologic forms in *Puccinia graminis tritici* differed in the comparative morphology of the spore forms. Waterhouse (1930) also pointed out that any two biologic forms might differ greatly in their spore measurements. In a recent investigation, the present authors (1957) noted morphological variations in *Puccinia penniseti* Zimm., as indicated by width-to-length ratio of the uredospores and suspected the possibility of existence of three distinct biologic forms. In the present investigation, rust samples from 22 localities from various parts of the country were studied in order to investigate and to verify the possibility of such morphological variations in this rust.

MATERIAL AND METHOD

Monosporous cultures of the rust samples obtained from the localities given below were established on Agra Local *bajra* variety. The rusts were raised on the same host for three generations under identical environmental conditions in green house so as to acclamatise the rust. Following the technique of Levine (1928), one hundred mature uredospores of the third generation, of each sample of the rust were measured for their length and width and width-to-length ratios calculated. The data was analysed statistically following the 'analysis of variance' method as shown below :—

(*i*) Samples from 12 localities closely situated in Agra District:
Achnera, Bichpuri, Chaleshwar, Etmadpur, Jagadishpura, Kailash, Kheria, Kuberpur, Raibha, Runkuta, Shahdra and Shamsabad.

(*ii*) Samples from localities closely situated in Meerut District:
Meerut-1 (Victoria Park), Meerut-2 (Sports Colony), Meerut-3 (Garh Road), Meerut-4 (Nauchandi Road) and Meerut-5 (Hapur Road).

(*iii*) Samples from localities widely separated:
Agra, Coimbatore, Hyderabad, Kanpur, Lakhimpur Kheri, Meerut and Poona.

(*iv*) Samples from all the above 22 localities.

The critical difference (C. D.) at 5 per cent level is given along with the mean values in the results.

RESULTS

STATEMENT 1

Width-to-length ratios of uredospores of *Puccinia penniseti* Zimm. in samples from closely situated localities in Agra District.
Mean of one hundred observations.

Raibha	1·3955
Shahadra	1·3793
Etmadpur	1·3577
Kailash	1·3368
Runkuta	1·3305
Kheria	1·3212
Jagadishpura	1·3201
Bichpuri	1·3192
Shamsabad	1·2931
Chaleshwar	1·2904
Kuberpur	1·2767
Achnera	1·2651
C. D.	0·0352

Twelve samples were collected from various localities in Agra District. The ratios on comparison revealed the existence of three apparently distinct groups with merging of one group into the other. The three groups include the following localities :—

(*a*) Raibha, Shahadra and Etmadpur ; (*b*) Kheria, Jagadishpura and Bichpuri and (*c*) Shamsabad, Chaleshwar, Kuberpur and Achnera. However, Kailash and Runkuta were common to the categories (*a*) and (*b*).

It may be pointed out that the grouping is arbitrary. Etmadpur has been included in category (*a*) as it does not differ significantly from Shahadra. Shamsabad and Chaleshwar, although included in group (*c*) show a tendency to merge in group (*b*). The three categories are obvious even if we remove the merging localities.

STATEMENT 2

Width-to-length ratios of uredospores of *Puccinia penniseti* Zimm. in samples from closely situated localities in Meerut District.

Mean of one hundred observations.

Meerut-5	1·3744
Meerut-2	1·3521
Meerut-1	1·3352
Meerut-4	1·3324
Meerut-3	1·2912
C. D.	0·0390

The five samples from Meerut District indicate significant differences in relation to width-to-length ratios of the uredospores; the value for sample 5 is the highest, and for sample 3 the lowest. Evaluating the significant differences, the collections can be grouped under three distinct categories; Meerut-5; Meerut-1 and Meerut-4; and Meerut-3. The position of Meerut-2 is, however, controversial since it merges both with the first and the second category.

STATEMENT 3

Width-to-length ratios of uredospores of *Puccinia penniseti* Zimm. in samples from widely separated localities.

Mean of one hundred observations.

Lakhimpur Kheri	1·3999
Poona	1·3438
Kanpur	1·3395
Meerut	1·3352
Coimbatore	1·3236
Agra	1·3201
Hyderabad	1·3002
C. D.	0·0352

Rust collections from seven distantly situated localities were studied for the width-to-length ratios for their uredospores. The statistical analysis revealed that the uredospores from all the localities were not of the same dimensions; the ratios differed significantly and three categories could be formed. One locality (Lakhimpur Kheri) was distinct from the rest and had the maximum ratio. The remaining places fell in two categories; Kanpur and Poona having one type of ratio significantly higher than for Hyderabad. Meerut, Coimbatore and Agra represent the middle group since on one hand they have similar values for their uredospore dimensions to those of Poona and Kanpur while on the other hand they are not significantly different from those of Hyderabad. Thus it could be pointed out,

that in these lacalities there are three distinct groups based on width-to-length ratios for uredospores ; group A has a solitary locality, Lakhimpur Kheri, while Poona, Kanpur and Meerut come in group B, and group C represents Coimbatore, Agra and Hyderabad.

STATEMENT 4

Width-to-length ratios of uredospores of *Puccinia penniseti* Zimm. in samples from all the twenty-two localities.
Mean of one hundred observations.

Lakhimpur Kheri	1·3999
Raibha *	1·3955
Shahadra *	1·3793
Meerut 5 **	1·3744
Etmadpur *	1·3577
Meerut-2 **	1·3521
Poona	1·3438
Kanpur	1·3395
Kailash *	1·3368
Meerut-1 **	1·3352
Meerut-4 **	1·3324
Runkuta *	1·3305
Coimbatore	1·3236
Kheria *	1·3212
Jagadishpura *	1·3201
Bichpuri *	1·3192
Hyderabad	1·3002
Shamshabad *	1·2931
Meerut-3 **	1·2912
Chaleshwar *	1·2904
Kuberpur *	1·2767
Achnera *	1·2651
C. D.	0·0352

* Agra District ** Meerut District

All the twenty-two samples for the various localities throughout the country were analysed in one calculation so as to reveal the existence of distinct categories for uredospore dimensions. Here again the presence of three groups is quite

distinct although overlapping of one group with another is quite prominent. Avoiding merging of one group into another the three categories are as follows :—

(*a*) Lakhimpur Kheri and Raibha ;

(*b*) Meerut-2, Poona, Kanpur, Kailash, Meerut-1, Meerut 4, Runkuta, Coimbatore, Kheria, Jagadishpura and Bichpuri and

(*c*) Kuberpur and Achnera.

If all the collections are considered together, it is clear that the remaining localities have their ratios common to two groups. Shahadra, Meerut-5 and Etmadpur merge with category (*b*) while Shahadra and Meerut-5 are close to category (*a*). Similarly Hyderabad, Shamsabad, Meerut-3 and Chaleshwar have satistically non-significant differences for their ratios either with category (*b*) or (*c*).

GENERAL CONSIDERATIONS

Studies on biometry of uredospores of *Puccinia penniseti* Zimm. indicate that the uredospores in the samples studied differed significantly, although proper care was taken to acclimatise the pathogen on Agra Local *bajra* variety under identical environmental conditions in a green house and the mature uredospores from the third generation were picked for width-to-length ratios. It is evident from the above statements that three distinct categories of the rust exist in with-to-length ratios.

Levine (1928) pointed out that differences between various biologic forms of *Puccinia graminis tritici* are pronounced and significant. Waterhouse (1930) also indicated that two biologic form of *Puccinia triticina* Erik. differ in their uredospore measurements, thus confirming the possibility of determining biologic forms from a biometrical study of the uredospores. In the present investigation samples from distant localities as well as from the neighbouring localities show similar variations as to width-to-length ratios of the uredospores of the rust. The presence of distinct categories in all the studies throughout indicates the possibility of the existence of three biologic forms and the results are in consonance with those obtained by the authors in their preliminary investigations (1957).

In classifying the rust samples into three groups, physiologically distinct, the intermerging samples can be deleted if categories are arranged on ranges for their width-to-length rations. All the samples have the ratios ranging from 1·2651 to 1·3999. Three distinct groups are possible, ranging from 1·26 to 1·30; 1·32 to 1·36 and 1·36 to 1·40. The categories based on this assumption include the following :—

(*a*) Achnera, Kuberpur, Chaleshwar, Meerut-3, Shamsabad and Hyderabad.

(*b*) Bichpuri, Jagdishpura, Kheria, Coimbatore, Runkuta, Meerut-4, Meerut-1, Kailash, Kanpur, Poona, Meerut-2 and Etamadpur, and

(*c*) Meerut-5, Shahadra, Raibha and Lakhimpur Kheri.

This grouping has got the support from statistical analysis.

Besides throwing light on the probable existence of physiologic races, the biometrical results will be useful in aeriobiological studies with regard to the rust which will be taken up at a later date.

SUMMARY

Monosporous cultures of the rust samples obtained from twenty-two localities were established on Agra Local *bajra* variety. The rusts were raised on the same host for three generations under identical environmental conditions in a green house so as to acclamatise the rust. Following the technique of Levine (1928) one hundred mature uredospores of the third generation, of each sample of the rust were measured for their length and width and width-to-length ratios calculated. The data was analysed statistically following the 'analysis of variance' method.

The results show similar variations as to width-to-length ratios of the uredospores in samples from distant localities as well as from the neighbouring localities. The presence of distinct categories in all the studies throughout indicates the possibility of the existence of three biologic forms.

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STUDIES ON FUNAMBULUS PALMARUM LINN., THE INDIAN PALM SQUIRREL:

PART IV. THE ARTERIAL SYSTEM

By

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The Arterial System of the Squirrel which is taught as a mammalian type throughout India differs considerably from that system in either the Rat or the Rabbit, accounts of the latter only being available to teachers and students of Zoology. The author has already given a detailed account of the *musculature* (Das, 1955). This is the first detailed account of the Arterial System of the Indian Squirrel.

The origin and course of the pulmonary arteris, the aorta, the arteries of the head and neck, the arteries of the trunk, the upper extremity and the lower extremity are all given in detail. Some of the main features are: (1) the innominate is very short and the right and left common carotids asymmetrical; (2) the right subclavian, gives rise anteriorly to vertebral, seapular, and sternal arteries, and posteriorly to crachial, pectoral, mammary and intercostal; (3) the left subclavian after originating from the systemic gives rise to similar but asymmetrical branches; (4) the plerenic, the coeliac, and the anterior mesenteric originate close together; (5) the posterior mesenteric lies at the junction of the iliacs; (6) the spermatics lie anterior to the ilio-lumbars, the right ilio-lumbar arising from the common iliac and not the dorsal aorta.

INTRODUCTION

The present contribution forms the fourth part of a series of detailed studies on the functional anatomy of the Indian palm Squirrel, which is used as a mammalian type in most of the universities of Ind'a, Burma, Pakistan and Ceylon. It is hoped that these studies will fill up a conspicuous gap in our knowledge of the Oriental Scivridae. General comparisons with other Rodents will be made in a later contribution. It may be stated, however, that the arterial system of the squirrel is very different from that of the rat or the rabbit.

THE PULMONARY ARTERIES

The pulmonary trunk, carrying impure blood from the right ventricle to the lungs, arises from the left anterior angle of the right ventricle. Its base is almost as thick as the aorta and the entrance is guarded by three *semilunar valves*. It travels

as a single trunk over half the width of the left auricle and then branches into two, the right and the left *pulmonary arteries*, each going into its respective lung. At the point of separation of the right and left pulmonary arteries a *ligamentum arteriosum* connects them with the aorta as a solid band of connective tissue. The right pulmonary artery runs dorsal to the aorta and the left ventrally just after they fork from the pulmonary arch. Each pulmonary artery divides into two branches just before entering the lung, each of which runs parallel to its own pulmonary vein within the lung lobes. After entering the lung the branches divide and subdivide and finally merge into the capillaries of the alveoli.

THE SYSTEMIC ARTERIES

The single systemic (left) forms the *aorta* which is the largest artery in the body and carries the entire blood supplied to the head, trunk and limbs.

The aorta arises from the right anterior angle of the left ventricle, ascends beyond the fork of the pulmonary trunk and then curves gently downwards to the left passing dorsal to the left auricle through the pulmonary fork. From the anteriormost part or summit of the aorta, is given off a stout but short *innominate artery* which branches immediately into the right and the left common carotid, the right one forking from the right subclavian upto which the innominate may be said to extend. Just where it bends to the left it gives off the left subclavian artery and then becomes the *dorsal aorta.* The dorsal aorta curves medially in the middle of the thorax laying just ventral to the thoracic vertebrae. The aorta may be broadly divided into four regions: (1) *the ascending aorta* lying in the pericardium; (2) *the arch* of the aorta extending upto the left sub-clavian artery; (3) *the thoracic aorta* upto diaphragm; and (4) the *abdominal aorta* up to bifurcation into iliacs.

ARTERIES OF THE HEAD AND NECK

The Common Carotids. The *right common carotid* arises from the innominate, just as the right subclavian is given off to the right, and runs forward from the thoracic into the neck region on the right side of the trachea. On reaching near the thyroid (*i.e.*, the anterior region of the neck) it divides into an internal (or dorsal) and an external (or ventral) carotid. The *left common carotid* arises from the base of the innominate and runs forward on the left side of the trachea, adjacent to the oesophagus and on reaching the thyroid also divides into an internal and external carotid. The brahches of the external and internal carotids of both sides are almost symmetrical in most of the squirrels examined by the author.

The External Carotids. Each external carotid is more superficial and placed more medially than the internal carotid. It supplies blood through its various branches to the thyroid gland, the tongue, the throat, the face and the orbital region. Its main branches are: the Tracheal, Thyroidean, Cervical, External maxillary, Internal maxillary and the Lingual arteries. The external carotid after its origin, gives one branch to the thyroid and another to the trachea internally, while externally it sends a branch to the throat. It then runs forward and ascends the occipital region of the head, where it branches into an internal lingual, an external maxillary and a dorsal internal maxillary.

(1) *Tracheal*: This is the first branch of the external carotid medially, lying almost opposite the internal carotid artery, which arises dorsally and supplies the trachea.

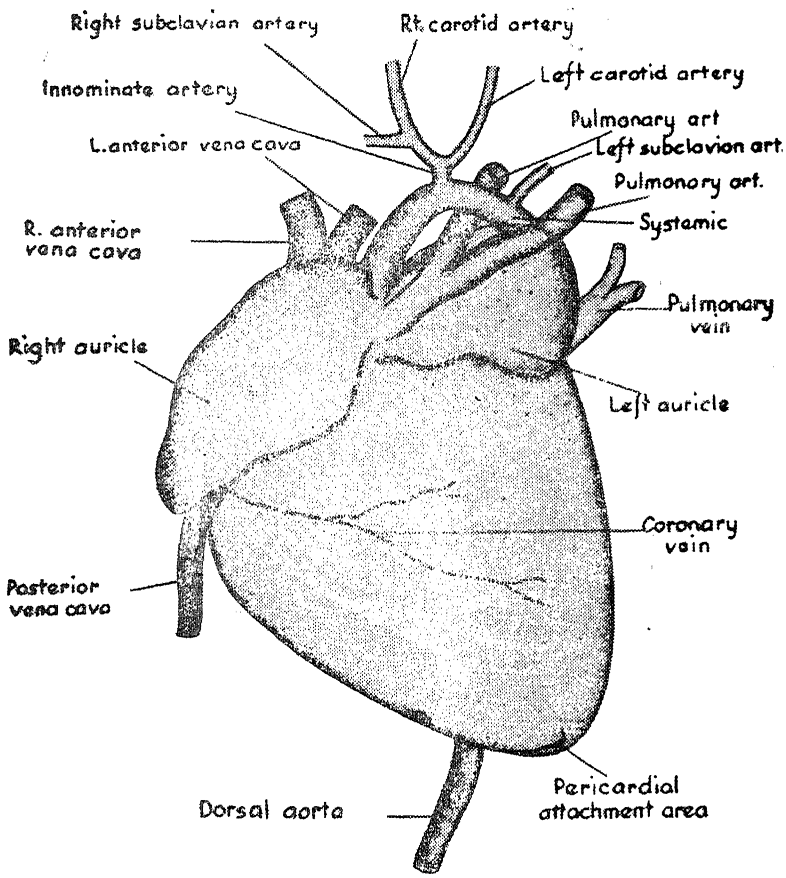

Fig. 1. The Heart with main blood vessels arising from it (Ventral view.)

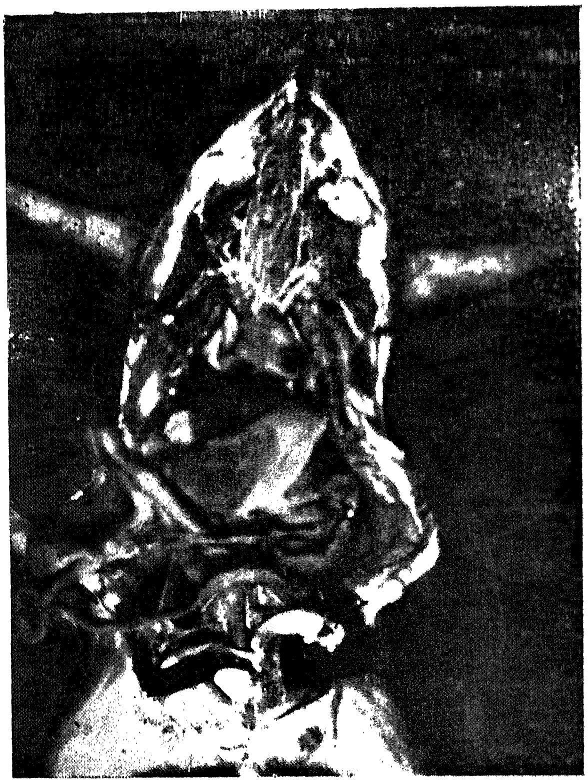

Fig. 2. The anterior arteries, heart and vi·era in situ

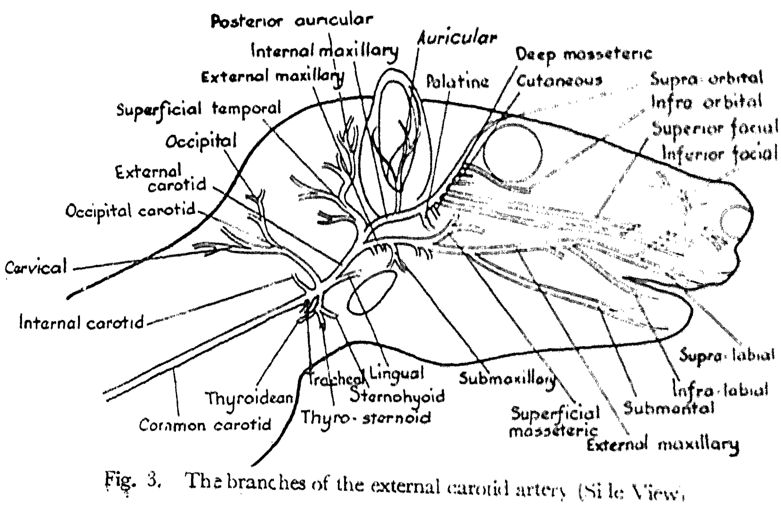

Fig. 3. The branches of the external carotid artery (Side View)

(2) *Thyroidean* : Arises medially opposite the cervical artery and immediately branches into the thyroid gland, the thyrosternoid muscle and the sternohyoid muscle, supplying blood to these organs.

(3) *Cervical* : or occipital carotid arises immediately anterior to the internal carotid and opposite the thyroidian. It gives two main branches : (*i*) *the occipital*, supplying that region of the head and (*ii*) the *cervical*, supplying throat.

(4) *External maxillary* : is a stout artery passing outwards and upwards along the medial border of the mandible, and gives the following branches : (*i*) the *digastric*, supplying the digastric muscles ; (*ii*) the *occipital*, supplying the sides of the occipital region of the head; (*iii*) the *sub-maxillary*, supplying the sub-maxillary gland; (*iv*) the *sub-mental*, supplying the chin; (*v*) the *masseteric* supplying the large masseter muscles ; and it finally forks at the angle of the mouth into (*vi*) the *inferior labial*, supplying the lower jaw and lip ; and (*vii*) the *superior labial* supplying the upper lip and also the nose by branching into anterior and posterior nasals.

(5) *Internal maxillary* : is shorter than the external maxillary and lies dorsal and inner to it, ascending almost in a straight line upto the posterior end of the orbit. During its course it gives the following branches : (*i*) the *superficial temporal* passing dorsally and branching into a temporal and a posterior auricular artery supplying the base of the ear ; (*ii*) the *auricular*, arising dorsally and branching into the external ear ; (*iii*) the *palatine*, supplying the roof of the bucco-pharyngeal cavity ; (*iv*) a *deep masseteric*, to the masseter ; (*v*) a *superior* and an *inferior facial*, to skin and muscles of the face ; (*vi*) a *cutaneous* supplying the skin of the cheeks and the platysma; and finally branches at the posterior end of the orbit into (*vii*) a *supra-orbital* and (*viii*) an *infra-orbital* artery.

(6) *Lingual* : branches out just before the origin of the external maxillary and, lying inner to it, passes almost in a straight line up to the ventral end of the chin. The Lingual artery gives off the following branches : (*i*) a *stylo-glossic* to styloglossus muscle ; (*ii*) a pair of *hyoideans* to the hyoid region of the throat ; (*iii*) a *lingual* to the tongue ; (*iv*) a *genioglossic* to the genioglosses muscle ; and (*v*) a *hyoglossic* to the hyoglossus muscle.

The Internal Carotide : Each internal carotid arises dorsally near the tracheal artery lying almost at right angles to the common carotid, and passes deeper than the oxternal carotid. It is narower in calibre than the external carotid, and after a short distance of its origin, penetrates the cranium through the intrnal carotid foramen lying on the tympantic bulla. It passes straight through the inner side of the neuro-cranium laterally and on reaching the brain joins with the *basilar artery* to form the *Circle of Willis*, an arterial anastomosis at the base of the brain. During its course each internal carotid gives out the following branches :

(1) *Stapedial* : Arises on level with the origin of basilar artery, and runs internally to supply the internal and middle ear.

(2) *Ophthalmic* : Supplies the eye ball and the eye muscles.

(3) *Cerebral* : These are three on each side, the posterior, the middle and the anterior cerebral arteries, which supply the corresponding regions of the brain.

(4) *Circle of Willis* : It is formed by the union of the anterior cerebral arteries with each other through the anterior communicating artery to form a semicircle anteriorly, and by union of the posterior cerebral arteries

through the posterior communicating artery with the fork of the basilar artery of its side, which is formed by the median of the two vertebral arteries at the base of the brain. The circle of Willis not only equalises the circulation of blood in the brain but also ensures blood-supply to the brain in case of destruction of one of the other arteries.

ARTERIES OF THE UPPER EXTREMITY

The Subclavian. The right subclavian arises from the end of the innominate where the latter is continued anteriorly as the right common carotid, while the left subclavian arises from the arch of the aorta where it forms the descending aorta. Each subclavian passes a short way up into the neck and then turns downwards to lie on the first two ribs where it gives off the first branch, the *vertebral* anteriorly. Then in gives off six more branches, making a total of seven in all, six, the *Scapular*, the *Sternal*, the *Thoracic*, the *Brachial* anteriorly, the *Pectoral* and *Anterior intercostal* posteriorly.

(1) *The Vertebral* : of each side arises very near the trachea and bends dorsally to pass into the vertebrarterial canal of the cervical vertebrae, giving off segmental arteries in the neck region. The two vertebrals unite anteriorly at the base of the medulla oblongata to form the *median basilar artery* which joins the circle of Willis already described. Just before their union each vertebral artery gives off a small branch posteriorly which immediately unites with its fellow and forms the *spinal artery* supplying the spinal cord.

(2) *The Scapular* : arises from the anterior face of the subclavian almost opposite the intercostal and passes obliquely forward into the muscles of the neck and the scapula.

(3) *The Sternal* : although dorsal in origin, curves ventrally to send branches to the sternum and the lateral thoracic muscles.

(4) *The Thoracic* ; is a stout artery which also arises from the anterior face of the subclavian near the arm-pit but immediately curves beneath the brachial to send branches into the lower thoracic and upper abdominal muscles, and the axil of the arm. It runs beneath the skin in the latero-ventral sides of the thorax and abdomen.

(5) *The Brachial* : arises from the subclavian, as a continuation of the latter, extending beyond the arm-pit and passing into the forelimb. On reaching the elbow each brachial divides into an inner radial and an outer ulnar artery both giving branches into the forearm and hand, and the fingers, supplying them with blood.

(6) *The Pectoral* : arises from the ventral side of subclavian and immediately branches out into the great and lesser pectoral muscles to distribute blood extensively in them.

(7) *The Anterior Intercostal*: arises from the posterior surface of the subclavian, almost opposite the scapular, one on each side of the thorax and sends paired branches segmentally in the anterior intercostal spaces to pass lateral to the thoracic wall. It supplies blood mainly to the anterior intercostal muscles.

ARTERIES OF THE TRUNK

After the left subclavian is given off the descending aorta may be differentiated as the *thoracic aorta* up to diaphragm and the *abdominal aorta* up to bifurcation of iliacs. This is also called the *dorsal aorta*. In the anterior region of the thorax the thoracic aorta gives off eight pairs of small *posterior intercostals*, paired *vertebrals*, an *oesophageal*,

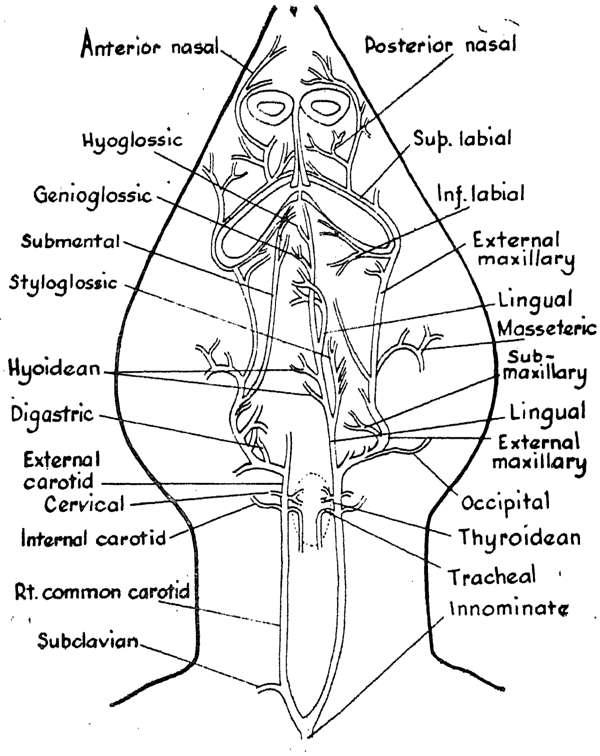

Fig. 4. The branches of the external carotid artery

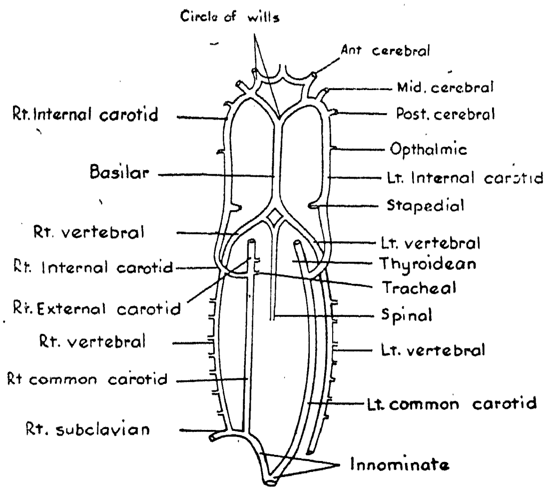

Fig. 5. The branches of the Internal Carotid artery.

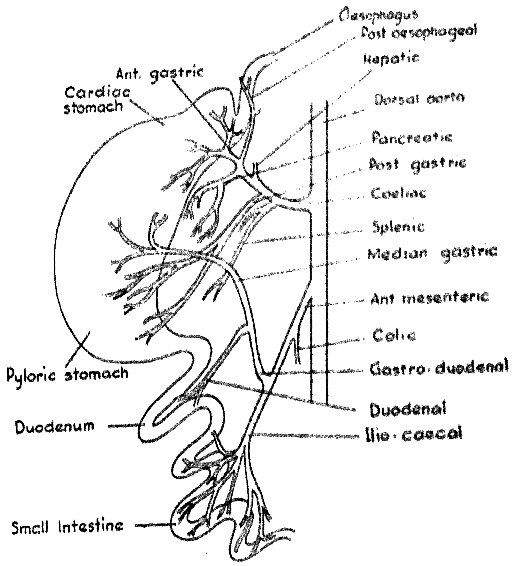

Fig. 6 The branches of the Coeliacs and Anterior Mesentric Arteries.

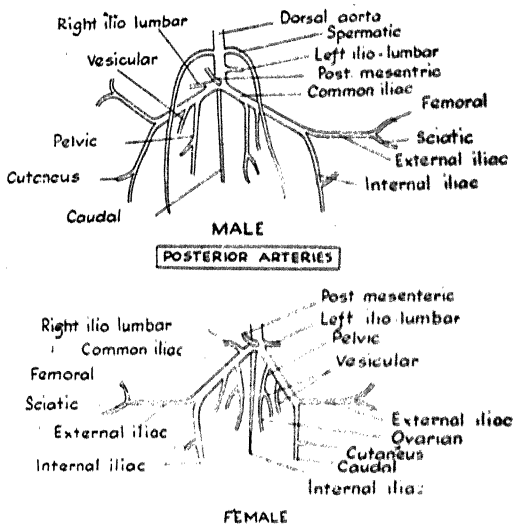

Fig. 7. Posterior Arteries of Male and Female Squirrel.

and an *anterior phrenic* artery to the anterior face of the diaphragm. Then the aorta penetrates the diaphragm and enters the abdominal cavity as the abdominal aorta, giving off four unpaired and three paired arteries before it forks to form the iliacs.

A. The aortic arteries:

(1) *The Posterior Phrenic*: is a single artery arising from the aorta on the posterior face of diaphragm which it supplies.

(2) *The Coeliac*: is an unpaired artery arising more often than not on the right side of the aorta just below the diaphragm, and passing immediately in an antero-lateral direction. It is a stout vessel in the squirrel supplying blood to the liver, the stomach, the pancreas, the spleen and the oesophagus. The first branch (i) the *splenic* arises posteriorly and runs beneath the stomach to reach the spleen; (ii) the *posterior gastric* is the next to be given off almost parallel to the splenic and sends blood to the pyloric stomach; (iii) the *hepatic*, the third branch originates, on the anterior face of the coeliac and branches immediately in two-one being the cystic artery supplying the gall bladder; (iv) the *pancreatic*; (v) the *anterior* gastric; and (vi) the *oesophageal*, represent the three terminal branches of the coeliac, the pancreatic being the largest of the three.

(3) *The Anterior Mesenteric*: arises as an unpaired artery a little behind the coeliac and runs immediately in a postero-lateral direction. The first branch (i) is the *colic* artery supplying the colon posteriorly; (ii) the *gastro-duodenal*, the next branch, passes anteriorly and forks into a *median gastric* supplying the wall of the stomach and a *duodenal* carrying blood to the duodenum; (iii) *the ileo-caecal*, the third branch, conveys blood to the entire small intestine, barring the duodenum.

(4) *The Lumbar*: is usually single and arises ventrally between the coeliac and the renals, dividing after its origin into 3 or 4 branches supplying the muscles and skin of the back.

(5) *The Renals*: are a pair of stout short arteries, one going to each kidney. The *right renal* artery arises far ahead of the *left renal* since the right kidney is well anterior to the left one. Each is directed outward and backward to form an acute angle with the aorta and gives off a *supra-reno-lumbar* branch to the suprarenal gland and back muscles of that region.

(6) *The Spermatics* : are a pair of arteries arising directly outward from the aorta at the same level after the renals. Each spermatic artery curves down and passes posteriorly through the inguinal canal into the testis of its side.

(7) *The Ilio-lumbars*: although paired, are situated asymmetrically, much more so than the renals. The left ilio-lumbar arises from the aorta laterally just before it forks into the iliacs, and supplies the ileum and back muscles of the lumbar region. The right ilio-lumbar on the other hand arises from the right common iliac, just after the fork, thus making the two entirely asymmetrical.

(8) *The Posterior Mesenteric*: is an unpaired thin artery arising medially from the ventral (front) wall of the aorta at the fork of the two common iliacs. It passes antero-laterally to supply the posterior colon and the rectum.

B. The Arteries of the Pelvis:

(1) *The common iliacs*: are rather long in the squirrel, arising by the posterior forking of the abdominal aorta in the pelvic region. Each common iliac gives off two arteries (i) the *pelvic* and (ii) the *vesicular* before it divides into the internal and the external iliacs. The vesicular supplies the bladder, while the pelvic supplies

the muscles of that region. In the female the pelvic sends a *uterine* branch to the uterus.

(2) *The Internal iliacs*: send branches to the pelvic walls, the external genitals, the pelvic muscles and the medial side of each thigh. The main vessel leaves the pelvic cavity as the *sciatic artery* passing to the side of the abductor caudae muscles.

(3) *The External iliacs*: each external iliac is the outer fork of the common iliac, which passes to the medial surface of the limb, being continued as the *femoral artery*.

ARTERIES OF THE LOWER EXTREMITY

(1) *Femoral*: lies in the upper half of each hind limb, and gives lateral femoral circumflex arteries laterally, as also branches to the abdominal walls, the external genitals and muscles of thigh. The femoral runs superficial upto middle of thigh and then becomes deep.

(2)*Popliteal*: Just above the knee-joint the femoral emerges as the popliteal artery at back of knee, and sends branches to the knee joint, the posterior femoral muscles, the gastrocnemius and soleus muscles. It forks below the knee to become the posterior tibial.

(3) *Posterior tibial*: runs down to the heel, and supplies the calf of the leg and also tibia and fibula. It gives another branch, the peroneal.

(4) *The Peroneal artery* : supplies the deeper muscles and the structures on the medial side of the fibula. The Poplitial gives off finally the anterior tibial artery.

(5) *Anterior Tibial* : supplied the front part of the skin of the leg and the foot, and is mostly superficial.

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